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COGNITIVE STYLE, INSTRUCTIONAL STRATEGY AND MATHEMATICS ACHIEVEMENT

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled COGNITIVE STYLE, INSTRUCTIONAL STRATEGY AND MATHEMATICS ACHIEVEMENT submitted by Frank Gene Marsh in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

DEDICATION

To my Mother and my Wife

who both sacrificed immensely that

I might attain my goals

ABSTRACT

The purpose of this study was to investigate the relationship between Witkin's cognitive style dimension of field-dependence-independence and mathematics achievement and its components of concept attainment and problem solving. The investigation utilized both student-centered and teacher-centered instructional strategies to determine if any instructional variation occurred in the investigated relationship. General ability and reflective intelligence were used as covariates in order to determine their relationship to field-dependence-independence and to partial out the ability of field-dependence-independence to predict mathematics achievement, concept attainment and problem solving scores after accounting for these variables.

The study employed eight grade eight mathematics classes and four teachers in two junior high schools. Each teacher used both a student-centered and a teacher-centered instructional strategy. Instructional materials were developed for the study and teachers were inserviced concerning their expected role in each strategy. Students had originally been randomly assigned to classes with attention given only to obtaining a balance by sex. The study progressed through the topics of Linear, Area and Angular Measurement and was of approximately four weeks duration.

The use of a Learning Environment Inventory indicated that students perceived the instructional strategies as different.

The results of the study indicated a significant relationship ($p \leq 0.001$) between measures of general ability, reflective intelligence,

field-dependence-independence, mathematics achievement, concept attainment and problem solving.

Field-dependence-independence proved to be a signficant single group predictor of mathematics achievement, concept attainment and problem solving scores. It also proved to be a significant predictor of mathematics achievement and concept attainment scores after accounting for reflective intelligence. After accounting for general ability or both general ability and reflective intelligence, field-dependence-independence was not a significant predictor of mathematics achievement, concept attainment or problem solving scores. As well, there was no instructional variation in the ability of field-dependence-independence to predict mathematics achievement or its component scores.

The study also produced evidence of no significant sex-related differences in mathematics achievement, concept attainment, problem solving or field-dependence-independence scores.

Arising from these findings were a number of implications for mathematics education and suggestions for further research.

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CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

I. INTRODUCTION

The search for a generally best method of mathematics instruction suggests that no single type of instruction will maximize learning for all students. To maximize learning, it is necessary to concentrate on the learner and specifically on his learning style.

Cronbach (1957) has suggested that researchers might design instruction to suit specific characteristics of learners. Instructional models for doing this may include capitalizing on the strengths of learners, compensating for weaknesses, providing remediation or adopting learner preference.

Research of this nature is characterized as Aptitude Treatment Interaction (ATI) research for investigating instruction and adheres to the belief that for different characteristics of learners, different results will be obtained with different methods of instruction.

A recent review of this ATI research has concluded, that although difficult to find, these interactions of aptitudes with treatments do exist (Cronbach & Snow, 1977). Suggestions are also made for research approaches and refinements which will provide increased understanding of the learning process.

Kilpatrick (1975) recommends the development or use of aptitude measures based on specific treatments. Behr and Eastman (1975) suggest that progress in ATI research in mathematics learning might first require the use of aptitude measures with a strong theoretical base and stable relation to performance.

Witkin's field-dependence-independence dimension of cognitive style is clearly an appropriate aptitude measure meeting these guidelines. Research reports by Witkin et al. (1949, 1950, 1952, 1962, 1977) covering the past three decades provide a sound theoretical base for field-dependence-independence and vast information on its relationship to learning in general and mathematics in particular.

Witkin et al. (1962) have reported that consistent differences exist in perceptual functioning and notably in the ability to perceive items as separate from their backgrounds or generally to overcome the influence of an embedding context. These differences have been shown to extend across intellectual functioning and personality characteristics. These individual differences define a hypothesized continuum from field-dependence to field-independence.

At the field-independent end of the continuum, the intellectual behavior is analytic and systematic; perceptual behavior is discriminating; emotional behavior is self-controlled; social behavior is independent and self-reliant; and motivational behavior is active and focused. At the field-dependent end of the continuum, the intellectual behavior is intuitive; perceptual behavior is undifferentiated; emotional behavior is impulsive; social behavior is dependent and other-directed; and motivational behavior is passive and diffused (Gruenfeld et al., 1973).

Evidence regarding concept-attainment tasks indicates that people who are competent in disembedding and restructuring tasks, that is field-independent, tend to adopt an hypothesis-testing approach to

learning. Such an approach signifies a participant role in learning. In contrast, people who are less competent in such tasks, that is relatively field-dependent, tend to adopt a more passive role in learning (Goodenough, 1976).

McLeod et al. (1978) suggest that this difference in anticipated learning roles is an important dimension for ATI studies using field-dependence-independence.

The provision of an instructional strategy which allows the individual to independently formulate, test, revise and reformulate hypotheses in order to attain intended concepts capitalizes on the strengths of the relatively field-independent student. The provision of an instructional strategy in which the intended concepts are presented by an instructor and student verified through examples, compensates for the anticipated more passive role of the relatively field-dependent student. That is, by varying the amount of teacher control and level of structure in instruction, the appropriate complementary instructional strategies are determined. The provision of a more teacher-centered instructional strategy to a field-dependent student fits the "compensatory" model and the provision of a more individualized or student-centered instructional strategy for the field-independent student fits the "preferrential" model of Salomon (1972).

Witkin et al. (1977) reports that field-independent people show a preference for mathematics and other related areas. The important instructional components of mathematics are the attainment of concepts

and the solving of problems. Varying instructional strategy to complement the student's cognitive style may enhance concept attainment. However, the solving of problems incurs the restructuring of or operating on concepts and might be more field-independent characteristic. That is, problem solving may require an ability which Skemp (1958) calls "reflective intelligence".

Sex-related differences in favor of males as are reported in mathematics achievement, are reported to occur in the cognitive style dimension of field-dependence-independence. Witkin et al. report that after age eight, sex-related differences occur with males being more field-independent. This lends some credence to the notion that mathematics or one of its components may be field-independent characteristic.

The general framework of this study is that of ATI research in mathematics learning. More specifically, the study searched for interactions between cognitive styles and instructional strategies which differed in dimensions related to teacher control and level of structure. In particular, the study investigated the relationship between field-dependence-independence and mathematics achievement in student-centered and teacher-centered instructional strategies. Concept attainment and problem solving as components of mathematics achievement, reflective intelligence and sex-related differences were investigated to shed more light on this relationship.

II. PURPOSE OF THE STUDY

The basic premise of this study is that the matching of instructional strategy to style of learning will produce optimum results. The study's purpose is to search for interactions between the cognitive style variable of field-dependence-independence and student-centered and teacher-centered instructional strategies using mathematics achievement and its components of concept attainment and problem solving.

Suggestions for precision in ATI research by Cronbach and Snow (1977) necessitated the inclusion of a measure of general ability and the consideration of other aptitude measures which may incorporate or be related to the aptitude of concern and the criterion measure. The aptitude measure of reflective intelligence of Skemp (1958) appeared to meet these criteria and was incorporated into the study.

The reported nature of sex-related differences in favor of males in both relative field-independence and mathematics achievement prompted a consideration of these differences.

The following questions explicitly summarize the purpose of this study:

1. What is the relationship between general ability, reflective intelligence and field-dependence-independence.

2. How is field-dependence-independence related to mathematics achievement and its components of concept attainment and problem solving, with and without general ability and reflective intelligence accounted for?

3. How is field-dependence-independence related to mathematics achievement and its components of concept attainment and problem solving in student-centered and teacher-centered instructional strategies, with and without general ability and reflective intelligence accounted for?

4. Are there any consistent sex-related differences in mathematics achievement and/or field-dependence-independence?

III. DEFINITION OF TERMS

Cognitive Style refers to the characteristic, self-consistent modes of functioning which individuals show in their perceptual and intellectual (i.e. cognitive) activities (Witkin et al., 1971).

Field-Dependence-Independence refers to the relative ability to function with greater or lesser autonomy of external referents, manifested in both the cognitive and social domains (Witkin and Goodenough, 1977).

Operationally, field-dependence-independence is a measure of the relative ability to separate and restructure elements from a prevailing field and refers to the score obtained on the Cf-1 form of the Hidden Figures Test.

Reflective Intelligence refers to the ability of the mind to become aware of and transform its own concepts and operations (Skemp, 1958).

Operationally, it refers to the score obtained on Skemp's Tests

of Operations Formation and Reflective Action with Operations.

<u>Mathematics Achievement</u> refers to the relative ability to identify, reflect upon, and operate with concepts to obtain solutions to questions and problems of concern.

Operationally, mathematics achievement refers to the total score obtained on the mathematics achievement test, covering the topics of linear, area and angular measurement and developed for the study.

<u>Concept Attainment</u> refers to the extent to which a concept is understood by demonstrating exemplars and non-exemplars of the concept.

Operationally, concept attainment refers to the score obtained on the concept attainment component of the mathematics achievement test developed for this study.

<u>Problem Solving</u> refers to the ability of a person to select among, relate and apply concepts to arrive at a solution to a problem of concern.

Operationally, it refers to the score obtained on the problem solving component of the mathematics achievement test developed for this study.

<u>General Ability</u> refers to the ability to perform on both verbal and non-verbal standard items devised to measure inate and experiencial aptitude and reflect relative scholastic potential.

Operationally, general ability refers to the composite score on both the verbal and non-verbal subtests of the Lorge-Thorndike IQ Test.

Student-Centered Instructional Strategy refers to a learning strategy in which the student has relative control over the rate of attainment of course objectives.

Operationally, in the student-centered instructional strategy materials were written on the topics of Linear, Area and Angular Measurement which provided the students with the objectives of the topics, posed questions for conjectural purposes, proposed tasks related to the questions and supplied information and opportunity to reflect upon their conjectures to attain the intended concepts. The student was responsible for progress through the materials and had to become actively involved in measuring tasks to complete the units. Exercises related to the concepts were provided throughout the unit to provide a diagnostic indication of student progress. The student was advised either to work alone or with another individual and opportunity was provided for the seeking and lending of peer assistance. A teacher was available at all times to provide tutorial help in the form of individual or group instruction when requested. At the completion of the materials, an assessment was given to each student to determine if the objectives were successfully attained.

This strategy emphasized student responsibility for learning. The teacher and materials were available to facilitate learning and meet the students' need.

Teacher-Centered Instructional Strategy refers to a learning strategy in which the teacher controls the rate of presentation and

completion of learning materials.

Operationally, in the teacher-centered instructional strategy the teacher was provided with a list of concepts relevant to the topics of Linear, Area and Angular Measurement and used text materials pertinent to these topics to prepare and teach the lessons in order to introduce the concepts. Essentially, the teacher provided group instruction and examples to introduce concepts, set explicit exercises from text materials pertinent to the instruction, allowed time for completion of exercises and at the appropriate time corrected the exercises. This was followed by instruction on the next topic in the same manner. Diagnostic assessment and review was provided by the teacher when requested or deemed necessary by the teacher. An assessment was given to all students after completion of the topics.

The characteristic feature of this strategy is teacher responsibility and control over instructional methods, materials and pacing. It is often referred to as the "traditional" instructional method.

IV. SIGNIFICANCE OF THE STUDY

Work by Witkin et al. (1949, 1950, 1952, 1962, 1977) has shown that consistent and marked individual differences exist in perceptual functioning. These differences have been shown to extend across intellectual functioning and personality characteristics and define a hypothesized continuum from field-dependence to field-independence.

A highly field-independent person may be described as analytic and systematic, independent, self-controlled and self-reliant and should prefer a learning environment which allows active involvement in structuring, organizing and analyzing instructional material in order to attain intended concepts.

A highly field-dependent person may be described as intuitive, impulsive, dependent, passive, other-directed and social-process oriented and should benefit most from a learning environment in which material is organized and presented in a structured fashion to specify intended concepts to be learned.

In general, Witkin et al. hypothesize that since strengths and weaknesses may be ascribed to both ends of the continuum and since strengths may be capitalized on and weaknesses compensated for, then field-dependence-independence is a value-free cognitive style dimension.

However, it is reported (Witkin et al., 1977) that relatively field-independent people prefer mathematics and closely related subjects and tend to have higher achievement in these areas. Thus, in most studies involving mathematics achievement, relative field-dependence-independence is considered as an aptitude measure. The necessary component to be added is the complementary instructional strategy to the cognitive style.

Instructional studies relating field-dependence-independence, instructional styles and mathematics achievement have been inconclusive. Thornell (1977) and Baldwin (1977) have found that field-independent students are either superior in achievement or do equally well in all

instructional situations. McLeod et al. (1978) report significant interactions between level of guidance and field-dependence-independence.

Witkin et al. (1977) hypothesize that if the compensatory model of structured learning for field-dependent students is used, so that material is presented in an organized, structured form, field-dependent and independent students would do equally well in learning concepts.

A clinical study by Blake (1976) of field-dependence-independence and problem solving confirmed that field-independent students are more successful problem solvers.

The important implication which arises from Witkin's hypothesis about concept attainment and Blake's study of problem solving is that any mathematics achievement difference in a compensatory model would be due to problem solving ability and not due to differences in concept attainment. It is attention to this implication which provided the major focus for the present study and provides its distinction from others in this area.

Cronbach and Snow (1977) after reviewing aptitude-treatment-interaction studies suggest that researchers should investigate aptitudes in hierarchial order. That is, firstly, general ability should be investigated with downward progression on some aptitude hierarchy until the aptitude of concern is reached.

Harrison (1967) found that after general ability was accounted for, the construct of Reflective Intelligence of Skemp (1958) was a significant predictor of mathematics achievement. However, its position on an aptitude hierarchy in relation to field-dependence-independence

needs to be established.

In following the suggestions of Cronbach and Snow (1977) and to further enhance the present study, it was necessary to investigate field-dependence-independence in terms of mathematics achievement and its components in light of both general ability and reflective intelligence.

The present study attempted to include suggestions to improve ATI research. Although studies have dealt with field-dependence-independence and complementary instructional strategies in mathematics, the present study focused on mathematics achievement and its components of concept attainment and problem solving. This focus was necessitated by the implications arising from the findings of the earlier studies.

V. DESCRIPTION OF THE STUDY

The following is an overview of the setting for the present study. A more extensive presentation and discussion appear in Chapter III.

The population from which the sample was drawn consisted of all grade eight students in two junior high schools under the jurisdiction of the Edmonton Separate School Board.

Each school contained four grade eight classes with two classes assigned to each mathematics teacher. Thus, the study involved eight classes and four teachers. Each teacher was provided in-service concerning the expected instructional strategies to be used and used a student-centered strategy with one class and a teacher-centered strategy with the other. Students' perceptions of their instructional strategy were determined using a Learning Environment Inventory. This was done

to determine if the instructional strategies were interpreted by students as being different.

The classes were heterogeneous in nature, since at the beginning of the year students had been randomly assigned with attention only to providing a balance of students by sex.

The study was conducted at the beginning of the year and lasted for a period of approximately four weeks.

Test instruments were researcher administered. Data was gathered according to the following schedule:

a). The Lorge-Thorndike IQ Test had been previously administered and was obtained from the school records.

b). The Hidden Figures Tests (HFT) was administered immediately before the initial class on linear measure.

c). The Reflective Intelligence Test was administered at the beginning of the second week of the study.

d). The Learning Environment Inventory (LEI) was administered immediately after completion of the angular measure unit.

e). The Mathematics Achievement Test was administered in the second class following completion of the angular measure unit and thus the measurement topics.

During the third week two students from each class, according to a low or high score of the HFT were interviewed. The purpose of the interview was to provide information on the students' perceptions of classroom instructional methods, style of problem solving, and general attitude towards mathematics. It was felt that this information would

benefit data interpretation at a later date. A consistent set of questions and problems was used with each student in this sub-sample.

The test instruments developed for this study had been piloted and necessary revisions made before being used in the study.

VI. MAJOR HYPOTHESES TO BE TESTED

The logical testing of the hypotheses in this study necessitated firstly considering the relationship between the aptitude measures. This was to provide an indication of relative overlap among the aptitude measures of general ability, reflective intelligence and field-dependence-independence. Hypothesis one reflects this need.

1. There will be no significant relationship between general ability, reflective intelligence and field-dependence-independence.

The aptitude of concern in this present study is field-dependence-independence. To determine whether field-dependence-independence could be used to predict mathematics achievement, and if so, whether this predictive ability holds for concept attainment and problem solving is the next task. This provides evidence on whether the field-dependent or field-independent students are generally superior and if so, is the achievement superiority due to one or both components of mathematics achievement.

Cronbach and Snow (1977) suggest that it is necessary to partial out the effect due entirely to the aptitude of concern by accounting for general ability and some related aptitude variables. From

hypothesis one an indication of the relatedness provides some expectation of whether field-dependence-independence would have a separate effect after general ability and reflective intelligence were accounted for. This must be confirmed in an attempt to establish any predictive ability of field-dependence-independence on mathematics achievement or its components. Hypotheses two and three reflect these requirements.

2. Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores.

3. Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores after general ability, reflective intelligence or general ability and reflective intelligence is accounted for.

Thus far, the hypotheses have dealt with mathematics achievement and its components and with the aptitudes which were considered. Instructional strategy effects must now be considered. Interactions between the instructional strategies and field-dependence-independence, both alone and after accounting for general ability and reflective intelligence, must be investigated. Mathematics achievement and its components of concept attainment and problem solving are the criterion variables. The possibility exists that interactions may occur using either of the mathematical component scores but not when using overall mathematics achievement. Hypotheses four and five incorporate these needed considerations.

4. Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores in either a student-centered or a teacher-centered instructional strategy.

5. Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores in either a student-centered or a teacher-centered instructional strategy after general ability, reflective intelligence or both general ability and reflective intelligence is accounted for.

Finally, the study was to determine if any sex-related differences occurred both in mathematics achievement and in cognitive style. An investigation of sex-related differences in the components of mathematics achievement was carried out to determine if any differences are component-related or are characteristic of mathematics achievement generally. Hypotheses six and seven reflect these considerations.

6. There will be no significant difference in the mean mathematics achievement, concept attainment or problem solving scores of boys and girls.

7. There will be no significant difference in the mean field-dependence-independence scores of boys and girls.

The preceding order of null hypotheses appeared to be the conceptually and statistically logical order to follow in answering the questions in the study.

VII. ASSUMPTIONS

In interpretation of the study the following assumptions must be considered:

1. The concepts and problems comprising the mathematics achievement test are a valid measure of mathematics performance at the grade eight level.

2. The 15 components of the Learning Environment Inventory sufficiently cover the range of aspects of a learning environment.

3. The Lorge-Thorndike I.Q. is a representative measure of general ability.

4. The characteristics of the teachers involved weren't accounted for. It was assumed that they are representative of teachers.

VIII. DELIMITATIONS

In interpretation of the study, the following delimitations will have to be considered:

1. The study is confined to grade eight, since major developmental changes in students will have stabilized by this time.

2. The study is restricted to classes selected from the Edmonton Separate School System.

3. Only the topic concerning Linear, Area and Angular Measurement was sampled.

IX. LIMITATIONS

In interpretation of the data, the following limitations will have to be considered:

1. The schools used were not randomly chosen. They were selected by School Board Personnel to be representative of their population.

2. The study only extended through the beginning month of the school year.

3. The results of the study will be restricted to groups similar to those involved in this study.

X. OUTLINE OF THE REPORT

Chapter II contains a review of selected relevant literature. A detailed account of the design of the study, the testing procedures used, the piloting of instruments, and the test instruments employed is reported in Chapter III.

Chapter IV reports the results of the data analyses. The final Chapter, Chapter V, includes a summary and discussion of the findings with reference to the questions posed. Also, a discussion of some of the educational implications of the findings and suggestions for further research are contained in this Chapter.

CHAPTER II

REVIEW OF THE THEORY AND SELECTED RESEARCH

I. INTRODUCTION

The purpose of this research was to establish the relationship between Witkin's cognitive style dimension of field-dependence-independence and mathematics achievement and its components in both student-centered and teacher-centered instructional strategies.

This Chapter provides an overview of the development and research concerning field-dependence-independence and establishes an expected relationship with mathematics achievement and instructional strategies. A possible relationship between field-dependence-independence and reflective intelligence in mathematics learning is also developed.

Finally, a section is presented which summarizes the conceptual link between the variables of field-dependence-independence, mathematics achievement and instructional strategies as it emerges for the study.

II. FIELD-DEPENDENT AND FIELD-INDEPENDENT COGNITIVE STYLES

The evolution of the cognitive dimensions of field-dependence-independence can be traced back about three decades. Early work was perceptual in nature and was concerned with how people located the upright in space (Witkin 1949, 1950, 1952; Witkin and Asch, 1948).

The test for this had its origins in the laboratory. Known as the Rod and Frame Test (RFT), a person was presented with a luminous square frame tilted from the vertical, and a luminous rod which could be moved clockwise or counter-clockwise independent of the frame. The subject

is presented with this task in a darkened room, the object is to align the rod in the vertical position. A subject's score is the angle deviation of the rod from the perceived and true vertical position. This test evaluates the individual's perception of the position in relation to the upright of an item within a limited visual field.

Another situation to determine the roles of the visual and bodily standards in perception of the upright is a two component Tilting Room-Tilting Chair Test. For this test, the subject is seated in a chair, which can be tilted clockwise or counter-clockwise; the chair is projected into a small room which can also be tilted clockwise or counter-clockwise independently of the larger room. After the subject is seated, the chair and the room are brought to prepared tilted settings and the subject is then asked to adjust the chair or room to a position where he experiences it as upright. A subject's score is his angle deviation from perceived and true vertical either by movement of the chair, body-adjustment test (BAT) or adjustment of the small room, room-adjustment test (RAT). These tests evaluate a subject's perception of the position of his body and of the whole surrounding field in relation to the upright and are structurally similar to the rod and frame situation.

A third situation made use of in early field-dependence-independence work requires a subject to separate an item from the field in which it is incorporated. It involves neither orientation toward upright nor body position. In the Embedded Figures Test (EFT), the subject is shown a simple figure, which is removed, and then a complex figure with the

simple figure embedded in it. A directive is given to locate the simple figure. This test was taken from Gottschalt's test for the study of past experience in perception. Coloured patterns were superimposed over the Gottschalt black and white outline figures to increase perceptual difficulty. The EFT list consists of twenty-four complex figures in each of which is a simple figure to be located. A maximum of five minutes is allowed per trial. The subject's score is the mean amount of time required to find the simple figures within the complex figures. This provides a measure of the extent to which a subject's perception is influenced by the context in which an item occurs.

In all three tasks early findings showed marked individual differences in performance. Witkin et al. (1977) reports that a self-consistency appears in performance across tasks. If the same person is tested in the situations examined, it is found that the person who tilts the rod far towards the tilted frame in making it straight is likely to be the person who tilts his body far towards the tilted room to perceive the body as upright, and he is also likely to be the person who takes a long time to find the simple figure in the complex design. Similar consistency has been found in tasks which extend across other sense modalities including for example, the selection of a simple tune from a complex melody, and with eyes closed, the feeling out of a simple figure, composed of raised contours, from a similarily composed complex figure (Axelrod and Cohen, 1961; White, 1954; Witkin, Birnbaum, Lomonoco, Lehr and Herman, 1968).

Witkin, in conceptualizing these differences, proposes that the

common denominator underlying the differences in performance in the various tasks is the extent to which the person perceives part of a field as discrete from the surrounding field as a whole. That is, it is the extent to which the organization of the prevailing field determines perception of its components. More simply, it is the extent to which the person perceives analytically.

Witkin (1950) defines these differences in perceptual behavior in the following way:

> "The mode of perceiving which reflects ability to deal with the field in an active analytical fashion and to differentiate objects from their background has been called 'field-independent analytical'. The opposite way of perceiving which reflects submission to the influence of the field and the inability to keep an item separate from its surroundings, we call 'field-dependent'"(p. 497).

To determine whether the perceptual differences were stable or transient was the next developmental step. Bauman (1951) in testing the reliability of Witkin's test battery and the stability of the perceptual behavior reported the following test-retest correlations after a three year period: RFT, r=.84 (male), .66 (female); BAT, r=.77 (male), .74 (female); and EFT r=.89 (male), .89 (female). Other researchers have found similar evidence to support these findings (Linton, 1952; Witkin, Goodenough & Karp, 1967, etc.).

A focus on sex differences noted differences between men and women (Witkin, 1949). These differences have been seen to exist in children as early as eight years(Witkin, Goodenough & Karp, 1967), and will be discussed in more detail later.

Harris (cited in Witkin et al., 1962) studied whether the same individual differences in perceptual behavior were apparent in problem solving tasks. She employed two problem solving tasks used by Duncker (1945) in which a solution to a structural situation can be obtained by using objects out of their normal context. Harris found that field-independent people easily overcame the predominant context of the objects and were significantly more successful in solving the problem.

Research using Rorschach inkblots or ambiguous stimuli (Witkin et al, 1962; Gump, 1955) linked analytical and structuring abilities in perception. This was further verified in studies of verbal material (Bruce, 1965; Klein, 1967) and structuring of curriculum content by high school teachers and students (Stasz, 1974). According to Witkin et al. (1977) this evidence linking structuring tendancies to the analytical tendancies of field-dependence-independence, suggested the individual differences being dealt with might best be conceived as an articulated-global continuum. That is, analysis and structuring are complementary aspects of articulation. Thus, the person who experiences in an articulated fashion seems to perceive items as discrete from background, when the field is organized, and to impose structure on a field and so perceive it as organized, when the field has little inherent structure. In contrast, experience is more global when it accords with the overall characteristics of the given prevailing field and involves less intervention of the acts of analyzing and structuring. This appears to be applicable to both perceptual and symbolic functioning.

Witkin et al. in conceptualizing this evidence on perceptual and

intellectual functioning state that:

> "It became clear that we were dealing with a broad dimension of individual differences that extend across both perceptual and intellectual activities. Because what is at issue is the characteristic approach the person brings with him to a wide range of situations - we called it his 'style' - and because the approach encompasses both his perceptual and intellectual activities - we spoke of it as his 'cognitive style', (1977, p.10)".

Further studies of the relationship of these cognitive styles to other variables have shown that they extend into other domains subsumed under personality.

Witkin and Goodenough (1977) report that the same contrasting styles appear in social behavior as in perceptual behavior. That is, field-dependent persons as opposed to more field-independent persons are likely to be more attentive to and use prevailing social frames of reference. It has also been documented that field-dependent persons tend more to social cues and are likely to be more attuned to social aspects of the environment. This has been evidenced in the field-dependent persons studying of faces of others as a primary source of what others feel and think (Konstadt and Foreman, 1965; Nevill, 1972).

Further findings, (Dingman, 1972; Oltman, Goodenough, Witkin, Freedman, & Friedman, 1975) show that field-dependent subjects are perceived as tactful, considerate, socially outgoing and affectionate and thus should have greater skill in getting along with people. In contrast, field-independent subjects are impersonally oriented and are more likely to be interested in the abstract and theoretical (Biggs, Fitzgerald & Atkinson, 1971; Heath, 1964).

Witkin et al. (1962) also report that these perceived individual styles can be seen in the domain of body-concepts and defenses. The field-independent subject experiences the body as having definite limits with discrete yet interrelated parts formed into a structured whole. Field-dependent subjects have a global concept of the body. In the defense domain, the field-dependent persons tend to use non-specific defense mechanisms such as repression.

In re-assessing the evolution of the work on cognitive functioning, it can be seen that the articulated-global dimensions of field-dependence-independence consistently relate to the perceptual, intellectual and personality domains.

A longitudinal study by Witkin, Goodenough & Karp (1967), has indicated a developmental progression from relative field-dependence to greater field-independence. This trend is evident until mid-adolesence at which time it levels off. Sometime furing middle age, however, there is a return to greater field-dependence, (Witkin et al., 1962). However, despite the general increase in differentiation during childhood and early adolesence, individuals appear to maintain the same relative position among their peers on measures of field articulation.

Measures of field articulation have been refined since the early stages of development. Witkin et al. (1977) report that in place of the complex gadgets required for earlier laboratory test of field-dependence-independence, there are now available simpler devices and group tests with good reliability, applicable to the complete age span (Witkin, Oltman, Raskin & Karp, 1971).

Honsberger (1976), in a summary, proposes that Witkin's theory, hypothesizes a developmental progression towards a differentiated state characterized by separated psychological functions, (i.e. perceiving from feelings; thinking from actions), an ability to analyze and structure experiences (i.e. articulation), and a separation of self from the environment.

Gruenfeld, Weissenberg and Loch (1973) summarize the characteristic behaviors at each end of the field-dependence-independence continuum as follows:

> "At the articulated end of the continuum, the characteristic intellectual behavior is analytic-systematic, the perceptual behavior is discriminating, the emotional behavior is independent and self-reliant, and the motivational behavior is active and focused. At the global end of the continuum, the characteristic intellectual behavior is intuitive, the perceptual behavior is undifferentiated, the emotional behavior is impulsive, the social behavior is dependent and other-directed, and the motivational behavior is passive and diffused", (p. 42).

It is rather obvious at this point, that a theory which predicts such diverse characteristic behaviors must have educational implications. A discussion of these implications and related research pertaining to sex differences, mathematics achievement, and instructional styles will follow.

III. FIELD-DEPENDENCE-INDEPENDENCE AND SEX DIFFERENCES

The study of possible differences between sexes was an early step in Witkin's evolution of the field-dependence-independence theory. As was mentioned earlier in this review, Witkin et al. (1962) reported that in Western societies there are persistent sex differences in field-dependence-independence beginning in early adolescence. These differences exist as early as eight years old.

Pysh (1970) concurs with these findings of no sex difference in children below seven years. Further studies with pre-school aged children (Massari & Massari, 1973) found no sex differences using the embedded-figures test. Keough and Ryan (1971) confirmed this with a sample of kindergarten children but did find a sex difference in favor of boys using the portable rod and frame test. Research, however, generally indicates no sex difference at this age level which is in accord with Witkin's findings.

In a report of a longitudinal study of cognitive style and academic choice and performance, Witkin (1972) has indicated that a pattern of more field-independent persons selecting science and mathematics courses seem to emerge. In college and high schools where choice is avilable, it appears that female mathematics majors are more highly independent than males. These findings suggest, that where course choice is available, the sex differences may be due to subject area researched rather than a dominantly consistent sex difference.

Cross-cultural studies in the Canadian North (Berry 1966), have

indicated no significant sex differences between Eskimo men and women on the embedded figures test. Evidence from other cross-cultural studies, (Witkin & Berry, 1975) indicate that sex differences in field-dependence-independence may be uncommon in mobile hunting societies and prevalent in sedentary, agricultural societies. That is, societies which are characteristically different in sex-role training and the value attached to the women's role may be characteristically different in the sex-related variation aspect of cognitive style. This suggests that sex-related differences may not be found in societies which do not encourage female dependency.

An inference from this hypothesis is that with the considerable change in the female role in North American society, there may no longer be sex differences in cognitive performance of field-dependence-independence. However, this may be true for only socially aware segments of the population.

Early research in mathematics almost always found male superiority in mathematics achievement (Glennon & Callahan, 1968). However, these sex-related differences do not appear to be as prevalent as earlier believed (Glennon & Callahan, 1975; Fennema, 1974). Although the results of the National Longnitudinal Study of Mathematical Abilities (NLSMA) and the National Assessment of Educational Progress (NAEP) reported sex differences in favor of males, Fennema and Sherman (1977) reported that sex-related differences were found in only half of the high schools studied if the number of years studying mathematics were controlled.

In a study of 1,320 grade six and eight mathematics students

enrolled in middle schools in Madison, Wisconsin, Fennema & Sherman (1978) found that not only did females not do better than males on low level tasks (computation) but males did not perform better than females on high level tasks (concepts, problem solving). They report that their results conflict with the NLSMA results of male superiority increasing with level of complexity. They suggest that the change in the role of women in society has changed female achievement patterns. This hypothesis has been presented by Maccoby and Jacklin (1974) with respect to all sex-related differences in intellectual abilities.

An assessment of sex differences in both cognitive style and mathematics achievement to test this hypothesis is necessary.

IV. FIELD-DEPENDENCE-INDEPENDENCE AND MATHEMATICS ACHIEVEMENT

Witkin et al. (1962) have proposed that the relative ability to separate an item from its context and the ability to structure unstructured situations as well as restructure, already structured situations is an important aspect of the different cognitive styles. Success in learning mathematics also includes these component abilities. That is, computation, learning of concepts and problem solving are functionally related to these abilities.

Witkin et al. (1977) in emphasizing the structuring hypothesis state that:

> "Frequently in learning, the material to be learned lacks clear inherent structure, creating the requirement that the learner himself provide organization as an aid to learning. Field-dependent persons are likely to have greater difficulty in learning such material compared to field-independent persons who are more likely themselves to provide the mediating structural rules that are needed to facilitate learning. On the other hand, when material to be learned is presented in an already organized form, so that structuring is not particularly called for, field-dependent and field-independent people are not likely to differ in their learning", (p. 21).

Following particular rules to do basic computation and the structured presentation of concepts in mathematics appears to compensate for the lack of structuring ability of the field-dependent student. However, in situations where the student must search for a correct concept, the field-independent student would have an advantage. That is, a concept attainment situation where the student role is passive is more suitable for the field-dependent student and one which the student is active, that is, trial and error search, is more suitable for a field-independent student. The type of learning situation is of paramount importance.

Wertheimer (cited in Hammond, 1976) in analyzing problem solving has stated that the finding of a correct solution requires the separation of problem components from the context of the situation and recombining them to form new relationships. This definition of problem solving, entails behaviors characteristic of relative-field-independence. It would be expected that a field-independent student would be better able to cope with this component of mathematics.

Blake (1976) conducted a clinical study to analyze the processes students used in solving mathematical word problems and to determine the

effect of problem context on these processes. A concomitant purpose was to determine whether students who differ in degree of field-independence, differ in the processes they use to solve mathematics problems. His sample consisted of forty subjects of both sexes who were completing a grade eleven academic mathematics program randomly selected from fourteen Algebra II classes. The subjects were administered Witkin's Embedded Figures Test and accordingly were match-assigned to a real-world or mathematical problem setting group. Subjects' tape-recorded protocols of problem solving procedures were analyzed by using a sequential coding of problem solving behaviors, and later matching the behaviors to personal characteristics.

Problem context proved to be unrelated to the heuristics used. Both total numbers and types used were not influenced by the problem setting. Subjects working problems in the mathematics world setting have more difficulty understanding the problems, but performed as well as the other group.

Field-independence had a marked effect on the use of heuristics and on the number of correct solutions obtained. The field-independent subjects used a greater variety of heuristics ($r=.33$) in attacking and solving problems; were more willing to change their mode of attack ($r=.27$); and obtained a greater number of correct solutions ($r=.30$) than their field-dependent counterparts.

Blake reported that the number of times a subject attempted to solve a problem was unrelated to obtaining a correct solution, while changing one's mode of attack in solving a problem was significantly

($p < .01$) related to obtaining a correct solution. An interesting observation was that field-independent students were more willing to check their work, usually by retracing the steps, whereas the field-dependent students usually re-read the problem.

This study by Blake is in accord with Witkin's hypothesized differences in components related to problem solving of students judged relatively field-independent or dependent. Any differences which occur in concept or factual learning may be due to the amount of structure provided by the instructional setting. Differences which occur in mathematics achievement may be due to cognitive style differences or to learning setting structure. An investigation of these crucial factors is necessary.

V. FIELD-DEPENDENCE-INDEPENDENCE AND INSTRUCTION

The importance of analyzing, structuring and restructing in information processing has been emphasized by Witkin et al. (1962) in differentiating relatively field-dependent and independent behaviors. Gruenfeld, Weinssenberg and Loch (1973) in summarizing the relative characteristic behaviors attributable to the differences in cognitive style refer to the field-dependent person as other-directed and thus the field-independent person as self-directed. Witkin et al. (1971) suggest that if the field-dependent student is presented organized material or presented material in an organized structured manner then this will compensate for deficiency in structuring ability. Thus, there will be compensation by cognitive style in instruction. The

field-independent student would profit less from such a teaching approach and would prefer less imposed structure.

In a programmed instruction study (Renzi, 1974), the amount of feedback given a subject was varied. Each subject was required to learn to draw an exact ellipse. In one version of a text, subjects were not given feedback about their performance when they attempted to draw the ellipses required. In a second version, a correctly drawn ellipse was provided as an overlay in the text. Results indicated that the performance of re-relatively field-independent college students was not influenced by whether or not they received feedback. In contrast, field-dependent students performed significantly better on the posttest when feedback was given.

Emmerich (cited in Witkin et al., 1977) in a study of teacher's and students' roles in the teaching-learning process found results consistent with Renzi. In an analysis of teacher's responses to a questionnaire he constructed for the study, Emmerich found that teachers described field-dependent students as profiting from "providing students with a plan", field-independent students were described as profiting less from such a teaching approach.

Salomon (1972) in a review of aptitude treatment interaction models discussed the "compensatory" and "preferential" models. The providing of structure and guidance to the field-dependent student would fit the compensatory model, the allowing of the field-independent student to work with less guidance in a less structured learning situation would fit the preferential model. Cronbach and Snow (1977) in a review of ATI studies point out that only a few studies examine the interactions

of field-dependence-independence with instruction.

Grieve and Davis (1971) conducted a study in which cognitive style, discovery and expository methods of instruction, and grade nine geography achievement was related. After a three week study of a unit on the geography of Japan under either a discovery or expository method, stuents were assessed using two tests, one at the knowledge level, the other at higher levels of the Bloom Taxonomy. For the entire sample of males and females there was a significant positive relationship between field-independence and performance at higher levels, but no interactions were found. After elimination of one-third of the sample scoring in the middle range of the Hidden Figures Test, the analysis showed a method by field-independence interaction for male subjects on both tests with the field-independent subjects scoring higher under the expository treatment. In the expository treatment, the generalizations were verbalized by the teacher as a first step in instruction. In the discovery treatment generalizations were not put into words until the end of the work period. Grieve and Davis suggest that the discovery method provided a more intense, personal and congenial social context which according to Witkin, field-dependent students would prefer.

Thornell (1977) studied the relationship between analytic/global cognitive styles and amount of written guidance provided to learners. Sixty fourth grade students were randomly assigned to either an 'intermediate' or 'maximal' guidance treatment differing in relative amount of written instructions. Using a median split of scores on the Children's Embedded Figures Test, each treatment was subdivided into

two cognitive style groups. This produced four subsamples of fifteen students differing in both instructional strategy and cognitive style. The groups worked through non-programmed, self-instructional booklets prepared by the investigator on selected geometric concepts for one hour per day, for three consecutive days. A power posttest consisting of twenty-five assessment items related to the geometric concepts was administered at the end of the three classes. Thornell found that neither level of guidance was more facilitative of learning with respect to either analytic or global subjects. A comparison of the performance of subjects of different cognitive styles showed that the analytic subjects did significantly (p .01) better regardless of treatment. Any interpretation of this study however, is limited by the short duration of the study and the similarity of the maximal and intermediate guidance treatments.

Baldwin (1977) in a study of the interaction of field-dependence and field-independence with method of instruction assessed the following hypotheses: firstly, field-dependent students, preferring interaction with people, would achieve more in mathematics if permitted to study in homogeneous groups of field-dependent or in heterogeneous groups of two field-dependents and two field-independents; secondly, the field-independent students would achieve equally well in individual study, homogeneous group study, or heterogeneous group study; thirdly, regardless of previous learning, field-independent subjects would score significantly higher than field-dependent subjects on the criterion test in logical equivalences.

To test the hypotheses, Baldwin used fifteen liberal arts mathematics classes at Nassau Community College. The groups were given the Group Embedded Figures Test with the top scoring one-third considered field-independent and the lower scoring one-third considered field-dependent. These students were then assigned to one of the three treatments; homogeneous, heterogeneous or individual study. A series of worksheets developed by the investigator was given to each group and after two and one-half seventy-five minute classes, a criterion test was given. A previous learning measure was used as a covariate in analyses.

The results substantiated only hypothesis two, that field-independent students would do equally well in either group. However, after dropping the covariate of previous learning, Baldwin concluded that the field-independent students did better regardless of the type of instruction. Again, however, the short duration of the study and the administering of the covariate test after the treatments limit any interpretation of these findings.

A well controlled, short-duration study of interactions between field-dependence-independence and two dimensions of discovery learning; levels of abstraction and level of guidance, was reported by McLeod et al. (1978).

Participants in the study came from four sections of a mathematics course for prospective elementary teachers. There were 120 participants randomly assigned to either of four treatment groups varying in level of guidance and level of abstraction. The treatments were minimum

guidance with manipulative materials, maximum guidance with manipulative materials, minimum guidance with symbolic presentation and maximum guidance with symbolic presentation. Each group worked through a packet of printed materials designed for their treatment group covering addition and subtraction in bases other than ten. Students were given 50 minutes to complete the treatment.

All subjects were given a pretest, two posttests, two retention tests four weeks later, and the Hidden Figures Test to measure field-dependence-independence. The two posttests and retention tests varied in level of abstraction.

McLeod et al. report that as predicted, field-independent students did better with minimum guidance, whereas field-dependent students excelled with maximum guidance. Although there was one interaction between field-dependence-independence and level of abstraction, no consistent pattern for this dimension was found.

As is pointed out by Cronbach and Snow (1977) the research relating field-dependence-independence to instruction has been inconclusive in the finding of interactional trends. After reviewing the studies, one can also conclude that their short duration may have been the limiting factor. The intended differences in treatments may have been insufficient to determine student difference. As well, using samples of college students will limit the generalizability of any findings to a school situation.

As Cronbach and Snow (1977) point out, a few findings suggest that it helps to make the treatment similar to the style as Witkin et al. (1977)

hypothesize. This hypothesis seems reasonable and fits a perferential or capitalization model. Only through further research into instruction and cognitive style will consistencies and generalizations be able to be pinned down.

VI. TECHNICAL SUGGESTIONS FOR ATI RESEARCH

Cronbach and Snow (1977) after reviewing the massive research on aptitude treatment interactions offer several suggestions which may strengthen further ATI research.

Firstly, they suggest that there is a need to collect data from instructional procedures that realistically progress through a body of material.

Secondly, they suggest that instruction should be continued long enough so that the student is thoroughly familiar with the style of instruction. This will normally be a minimum of a two week period.

Thirdly, samples should be sufficiently large to give the study sufficient power. Sample sizes in the order of 100 students are recommended.

Fourthly, when one characteristic is of special interest to the investigator additional aptitudes should also be measured. These extra measures should include at least one measure of general ability. This will provide evidence as to whether regression is due to the component of general ability. Other aptitude measures may include those having a conceptual relation to the aptitude of concern. Inclusion may be considered using a downward progression from general ability on some

aptitude hierarchy. This procedure will allow the investigator to determine any interrelations between the aptitude of concern and others which may include it. It will also provide the investigator with some conception of preciseness of regression accountability of the aptitude of concern.

These technical or procedural suggestions of Cronbach and Snow (1977; pp. 491-524) are offered to help guide new efforts to productively advance ATI research. An attempt was made to incorporate them in the present investigation.

VII. REFLECTIVE INTELLIGENCE AND FIELD-DEPENDENCE-INDEPENDENCE

In following the suggestion of Cronbach and Snow (1977) to use other aptitude measures than the one of specific concern, the measure of Reflective Intelligence was used in this study. Reflective Intelligence was devised by R.R. Skemp (1958) and specifically relates to mathematics thinking. It has been found to be a significant predictor of mathematics achievement (Harrison, 1967).

Skemp (cited in Harrison, 1967) defines reflective intelligence as:

> "The functioning of a second order mental system which can perceive relationships among and act upon the concepts and operations of the sensori-motor system, taking into account their relationship as well as information from the memory and the external environment" (p. 123).

The basis for reflective intelligence comes from Skemp's view that mathematical thinking is characterized by the process of exploration and generalization that derives new class-concepts and operations from

existing ones and applies these class concepts and operations in fields different from that of their origin. He views the development of mathematical ideas as almost entirely conceptual (Skemp, 1962).

It can be ascertained that Skemp's construct of reflective intelligence is mainly concerned with ability to attain concepts and to operate on or with these concepts. The second order mental functioning refers to the abstract manipulation of the concepts. That is, the use of the concepts in some form of mental manipulation.

The implication may be derived that reflective intelligence incorporates firstly, the ability to formulate concepts, and secondly, the ability to restructure or mentally operate on these concepts. That is, firstly the concepts are attained and secondly they are built upon, restructured, reformulated or otherwise used in some sense for some purpose.

Skemp (1971) describes the process as follows:

> "Both the formation of mathematical concepts and problem-solving activities are cognitive, organizing processes involving awareness of, modification of, and choice from among mentally represented operations. Such reflective activities make possible what is termed logical thought" (pp. 16-17).

This same basic implication was drawn from the research on field-dependence-independence. That is, field-dependence-independence refers to the relative ability to disembed from complex situations and may be a measure of the ability to structure concepts and in mathematical thinking may also provide a differentiation of students' ability to solve problems where restructuring of concepts, etc. is necessary.

It was asserted earlier, that providing complementary treatments to field-dependent and field-independent students would optimize concept attainment and that differences which might occur in the mathematics achievement of field-dependent and field-independent students may be due to problem solving ability.

It seems that reflective intelligence may also provide a discrimination here. It appears that a person of high reflective intelligence may be more capable at problem solving tasks than a person of lower reflective intelligence. However, this difference may or may not exist in concept attainment.

It seems that some conceptual link can be made between field-dependence-independence and reflective intelligence. The possibility exists that they may be alternate measures of the same aptitude; that reflective intelligence may be a measure of a higher order ability and thus differentiate problem solving ability in mathematics achievement; or that in some way reflective intelligence and field-dependence-independence are entirely different and distinct aptitudes.

The inclusion of reflective intelligence in this study will provide information of a possible relationship. It will also provide information on the relative positions of reflective intelligence and field-dependence-independence on an aptitude hierarchy.

VIII. SUMMARY

Work by Witkin et al. (1949, 1950, 1952, 1962, 1977) has shown that consistent and marked individual differences exist in perceptual functioning. These differences have been shown to extend across intellectual functioning and personality characteristics. These individual differences define a hypothesized continuum from field-dependence to field-independence.

At the field-independent end of the continuum, the intellectual behavior is analytic and systematic; perceptual behavior is discriminating; emotional behavior is self-controlled; social behavior is independent and self-reliant; and, motivational behavior is active and focused. At the field-dependent end of the continuum, the intellectual behavior is intuitive; perceptual behavior is undifferentiated; emotional behavior is implusive; social behavior is dependent and other-directed; and, motivational behavior is passive and diffused (Gruenfeld, et al., 1973).

Witkin et al. (1977) report that sex-related differences occur after age eight in favor of males. They hypothesize that field-independent people show a preference for mathematics and other related areas, and that level of structure in instruction should be varied to compensate for the cognitive style of the student. This fitting of instruction to style fits the compensatory and preferential models of Salomon (1972).

Results of the NLSMA assessment (Wilson, et al., 1972) indicate that mathematics achievement shows sex-related differences also in favor of males. However, research by Fennema and Sherman (1978) report that these differences especially in higher level tasks (concept attainment

and problem solving) do not often appear and when they do are not large. They hypothesize that sex-related differences in mathematics achievement may be changed due to the recent concern of the female role in society. This hypothesis has been presented by Maccoby and Jacklin (1974) in relation to all sex-related differences in intellectual ability and may extend to Witkin's hypothesized sex-related differences in field-dependence-independence.

Grieve and Davis (1971) conducted a study in which cognitive style, discovery and expository methods of instruction, and grade nine geography achievement was related. After a three week study of a unit on the geography of Japan under either a discovery or expository method, students were assessed using two tests, one at the knowledge level, the other at higher taxonomic levels. For the entire sample of males and females, there was a significant positive relationship between field-dependence and performance at higher levels but no interactions were found. After elimination of one-third of the sample scoring in the middle range of the Hidden Figures Test, the analysis showed a method by field-independence interaction for males on both tests with field-independent subjects scoring higher under the expository treatment. In the expository treatment, the generalizations were verbalized by the teacher as a first step in instruction. In the discovery treatment, generalizations were not put into words until the end of the work period. Grieve and Davis suggest that the discovery method provided a more intense personal and congenial social context which according to Witkin, field-dependent student would prefer.

Witkin et al. (1977) hypothesize that if the compensatory model of structured learning for field-dependent students is used, so that material is presented in an organized, structured form field-dependent and field-independent students would do equally well in learning concepts. However, problem solving in mathematics appears to be field-independent characteristic. Blake (1976) in a clinical study of field-dependence-independence confirms that field-independent students are more successful problem solvers. One might draw the implication that any mathematics achievement difference in a compensatory model would be due to problem solving ability and not due to differences in computation or concept attainment.

Instructional studies related to field-dependence-independence and mathematics achievement have been inconclusive. Thornell (1977) and Baldwin (1977) have found that field-independent students are either superior in achievement or do equally well in all instructional situations. McLeod et al. (1978) report significant interactions between level of guidance and field-dependence-independence. However, these studies are severely limited by the short duration of the study treatments.

Cronbach and Snow (1977) suggest that field-dependence-independence may be viewed as a component of general ability rather than as a cognitive style. In their framework, measures of field-dependence-independence would be viewed as fluid ability.

A further suggestion of Cronbach and Snow (1977) is that the researcher should investigate aptitudes in hierarchial order. That is, firstly, general ability should be investigated with downward progression

on some aptitude hierarchy until the aptitude of concern is reached. In the present study, the predictive ability of general ability must be accounted for before cognitive style (fluid ability) is investigated.

Harrison (1967) found that after general ability was accounted for, the construct of Reflective Intelligence of Skemp (1958) was a significant predictor of mathematics achievement. However, its position on an aptitude hierarchy in relation to field-dependence-independence is not known.

In following the suggestions of Cronbach and Snow (1977), it will be necessary to investigate field-dependence-independence in terms of mathematics achievement after accounting for general ability and again after accounting for general ability and reflective intelligence.

In reviewing aptitude treatment interactions, Cronbach and Snow (1977) point out that due to inconsistent findings and little research in the area, no consistent generalization can be made concerning field-dependence-independence and instructional strategies.

Witkin et al. (1977) in reviewing the implications of their research on cognitive style to education state that:

> "Attention to cognitive-style differences in learning under more structured and less structured conditions, and analysis of the problem-solving skills and strategies assumed for different learning tasks, are necessary".

A study of mathematics achievement using concept attainment and problem solving, sex-related differences and field-dependence-independence in both student-centered and teacher-centered instructional strategies relates to the theoretical model of Witkin et al. and attends to this

need. The accounting for general ability and general ability and reflective intelligence follows the guidelines for improving aptitude-treatment-interaction research of Cronbach and Snow.

CHAPTER III

RESEARCH PROCEDURES

I. INTRODUCTION

As was stated in Chapter I, the purpose of this study was to determine the relationship between cognitive style and mathematics achievement in two different instructional strategies. In particular, Witkin's cognitive style dimension of field-dependence-independence was studied in relation to mathematics achievement and its components of concept attainment and problem solving in both student-centered and teacher-centered instructional straegies. The research procedures employed for the study are discussed in this Chapter. This Chapter includes a description of the setting, instructional and sampling procedures, the test instruments used and the statistical procedures employed.

II. THE SETTING

The study involved grade eight students attending schools administered by the Edmonton Separate School Board. Initially, a request was made to the Edmonton Separate School Board for classes representative of their population to participate in the study. Two schools, each containing four grade eight classes, were provided. The schools were from different geographical locations.

At the beginning of the school year the students had been randomly assigned to classes with attention to preserving a balance of students by sex.

Mathematics instruction in each school was provided by two teachers

each responsible for two classes. Thus, the study employed eight classes and four teachers.

Each teacher was requested to use a student-centered instructional strategy with one class and a teacher-centered instructional strategy with the other class. In-service sessions were conducted with the teachers concerning their expected role in each strategy. A Learning Environment Inventory was employed as a quality control to determine if students perceived the instructional strategies as being different.

The study was conducted at the beginning of the school year and lasted for approximately four weeks.

During the study, the researcher administered the following test instruments:

a). The Hidden Figures Test before the study began.

b). Skemp's Reflective Intelligence Tests at the beginning of the second week of the study.

c). The Learning Environment Inventory immediately following the completion of the instructional phase of the study.

d). The Mathematics Achievement Test in the second class immediately following the completion of the instructional phase of the study.

The Lorge-Thorndike IQ test had been previously administered and was obtained from the school records.

As well, the researcher interviewed two students from each class concerning the students' perceptions of classroom procedures, ability in mathematics, general mathematics attitude, and style of problem

solving. This sub-sample was chosen according to a high or low score on the Hidden Figures Test. It was felt that the information gathered would benefit later data interpretation.

III. INSTRUCTIONAL PROCEDURE

The nature of the study dictated that it be carried out at the beginning of the school year. It was felt that student assessment of the learning environment during this time of year would be more accurate.

Materials were prepared on the topics of Linear, Area and Angular Measurement. These materials conformed with the objectives and materials used by the schools to teach the concepts contained in the measurement topics. These materials posed suggestions and questions and engaged the student in active measurement activities in order to obtain the concepts to be learned. Provision was made for the student to work alone or in small groups and to lend or seek peer assistance. A teacher was present to provide consultation and small group instruction if it was requested. The student was responsible for progress through the materials and was assessed for understanding after completion of the materials.

These materials were written to promote student responsibility for learning and were used specifically to obtain the student-centered instructional strategy used by four classes.

The remaining four classes used a teacher-centered instructional strategy. This strategy is generally referred to as 'traditional' instruction. The teacher used the text materials available to devise

lessons and instructed the students concerning the concepts to be attained. Essentially, the teacher provided group instruction using examples to introduce concepts. Eplicit exercises were set from text materials pertinent to the instruction and time provided for completion of the exercises. At the teacher-decided appropriate time the exercises were corrected and new instruction begun. An assessment was given to all students after completion of the measurement topics. This strategy was used because of its characteristic features of teacher control over and responsibility for instruction.

At the end of the instructional period (approximately four weeks) the Learning Environment Inventory was administered to assess students' perceptions of both the social and structural aspects of the strategies.

IV. THE SAMPLE

The population for the study came from eight grade eight classes from two schools under the jurisdiction of the Edmonton Separate School Board. These classes were contained in two Junior High Schools in different geographical locations of the City. The classes were chosen by the Board to be representative of those under the Board's jurisdiction.

The classes contained a total of 213 students of which 113 were males and 100 were females. Of this total, 101 students, consisting of 55 males and 46 females, used a student-centered instructional strategy and 112 students, consisting of 58 males and 54 females, used a teacher-centered strategy.

Due to incomplete data, mainly IQ scores a number of students were eliminated from score analyses. The final sample consisted of 177 students consisting of 97 males and 80 females. Table I shows a breakdown of the total sample by instructional strategy and sex.

TABLE I

INSTRUCTIONAL STRATEGY AND SEX OF STUDENTS

INSTRUCTIONAL STRATEGY	MALES	FEMALES	TOTAL
Student-Centered	46	40	86
Teacher-Centered	51	40	91
TOTAL	97	80	177

V. INSTRUMENTATION

In this section each of the instruments used to test the hypotheses stated in Chapter I is described.

Hidden Figures Test (HFT)

The HFT is a group test of extent of field-independence (Jackson et al., 1964). The Cf-1 form revised in 1972, consists of two 16-item halves with 12 minutes of completion time allowed for each half.

A set of five simple figures is given at the top of each page.

Each item consists of a more complex figure in which one of the five simple figures is embedded. The subject must locate the simple figure within the complex figure.

The HFT was used as a group test because of its ease of administration. Reliability is reported as follows:

1. .71 Jackson et al., 1964.
2. .79 Boersma, 1968.

Appendix A contains a copy of a sample item and instructions for the Cf-1 revised form of the HFT.

Skemp's Reflective Intelligence Tests (SK 6)

To determine a measure of Reflective Intelligence Skemp's Tests of Operations Formation and Reflective Action with Operations was used. These tests were developed by Skemp (1958) and revised by Harrison (1967) and found to be a predictor of mathematics achievement. The Sk 6 was designed to determine the students' ability to perform operations (Part I) and to mentally manipulate these operations (Part II).

The Sk 6 (Part I) consists of a demonstration sheet and a problem sheet. The student is provided three examples of each of ten operations and must determine the operations from the demonstration sheet. The problem sheet requires the student to perform each operation on three simple but abstract line figures for each operation. Typical operations include a clockwise rotation through a quarter-turn or a horizontal reflection. Thus, the subject has to make 30 responses.

The SK 6 (Part II) consists of the demonstration sheet and a problem

sheet. After being shown the operations on the demonstration sheet, the student is required to complete 15 questions. Five questions involve combining two operations; five involve reversing a single operation; and five involve first combining then reversing the operations.

Skemp (1958) reports reliability coefficients in the order of .94 (Sk 6, Part I) and .95 (Sk 6, Part II).

Appendix B contains a copy of the Sk 6 ((I) & (II)).

Learning Environment Inventory (LEI)

The LEI developed by Walberg and Anderson (1968) consists of 15 scales considered important in measuring the social and structural climate of a class as perceived by the pupils within it. Each scale consists of seven items with a range of four response choices from strongly agree to strongly disagree.

Table II provides a list of scales by item numbers and the alpha reliability coefficient for each scale.

The LEI was used to determine students' perceptions of differences in the student-centered and teacher-centered instructional strageties. The 15 scales were considered to cover a broad enough range to detect differences inherent in the treatments.

Appendix C contains a copy of the Learning Environment Inventory.

Lorge-Thorndike IQ Test

The Lorge-Thorndike IQ Test can be described as a series of abstract intelligence tests. They require the ability to work with ideas and relationships among ideas. The test is comprised of a verbal and a

TABLE II

LEARNING ENVIRONMENT INVENTORY -- SCALES, ITEM NUMBERS AND ALPHA RELIABILITY

	SCALE	ITEM NUMBERS							ALPHA RELIABILITY 1969
1.	Cohesiveness	1	18	32	56	*R58	R71	91	.69
2.	Diversity	4	11	34	37	72	86	95	.54
3.	Formality	7	16	48	R59	61	68	81	.76
4.	Speed	27	R73	R75	85	87	93	102	.70
5.	Environment	2	12	26	36	55	R57	90	.56
6.	Friction	8	30	44	68	82	88	103	.72
7.	Goal Direction	10	R23	R60	65	67	83	96	.85
8.	Favoritism	9	R14	22	24	49	74	98	.78
9.	Cliqueness	5	R20	28	31	76	R97	100	.65
10.	Satisfaction	6	17	R21	R38	52	63	79	.79
11.	Disorganization	3	19	R33	40	R45	70	94	.82
12.	Difficulty	13	46	R53	66	R78	R101	104	.64
13.	Apathy	39	50	54	R84	R89	92	R99	.82
14.	Democratic	25	29	R35	R42	51	62	R80	.67
15.	Competitiveness	15	41	43	47	R64	77	R105	.78

*R denotes an item with reverse polarity

non-verbal battery. The verbal battery provides a good index of scholastic aptitude while an estimate of scholastic aptitude not directly dependent on reading ability is provided by the non-verbal battery. Averaged together, the composite score provides a comprehensive and reliable measure of general intellectual ability.

The Lorge-Thorndike Test is given to all students of the Edmonton Separate School Board as part of a comprehensive testing program.

It is group administered. Scores for this study were obtained from school records.

Reliability for grade eight students is reported to be between .65 and .80 (Nyberg, 1969).

Mathematics Achievement Tests

The achievement test used in the study was developed by the investigator. Since concept attainment and problem solving were major considerations of the study, the test consisted of concept attainment, and problem solving components. The total achievement score was obtained by summing the component scores.

The topic of concern for this study was Measurement at the grade eight level. The test was comprised of items from Linear, Area and Angular Measurement.

Concept Attainment Component: The concept attainment section of the Mathematics Achievement Test consisted of five concept items from each of linear, area and angular measurement. These items reflected a generalization, notion or unit of measure inherent in or related to

linear, area or angular measure.

The concept items reflected the following necessary concept skills:

a). basic unit definition

b). recognizing unit size

c). estimation of unit size

d). relationship between units

e). conversion of units

The students were required to select the example or non-example from four given choices.

In task terms, each item was considered as a recognition of concept task and given a value of one. Thus, the total possible concept attainment score was 15.

Problem Solving Component: The problem solving component of the Mathematics Achievement Test is comprised of five problems. The problems involve either linear, area or angular measure. They were devised to involve three processes. That is, to solve a problem the student must analyze the problem, determine the concepts and act upon the concepts to arrive at a solution. Each problem was thus given a value of three because of the tasks involved.

The Mathematics Achievement Test is constructed so that it contains 20 questions. Items, 4, 8, 12, 16 and 20 are problem solving items. The others are concept attainment items.

Test-retest reliability for the test and its component parts are as follows:

1.	Mathematics Achievement Test	.93
2.	Concept Attainment Component	.85
3.	Problem Solving Component	.93

These were determined by utilizing a sample of twenty-five beginning grade nine students who had completed these topics the previous year. Test administrations were two weeks apart.

Appendix D contains a copy of the Mathematics Achievement Test.

VI. PILOT STUDY

A pilot study of the achievement test involving twenty-five students who were considered to have attained the objectives of the instruction, was conducted in early September, 1979. The purposes of this pilot study were to examine the following:

1. The wording of the questions to ensure that students understood the tasks required.
2. The test length. For administration purposes it was considered important to determine a suitable time period for completion of the test.
3. To determine if the questions suitably tested the attainment of objectives they were designed to test.
4. To determine a reliability coefficient for the test and its components.

The materials developed for the study and used in the student-centered strategy were given to a select group of mathematics educators including school teachers to determine their suitability.

On the basis of the study, the final modifications in the test and materials were made.

VII. STATISTICAL PROCEDURES

Since the purpose of this study was to test the ability of single and combinations of characteristics to predict mathematics achievement and to test for interactions between individual characteristics and instructional strategies, multiple linear regression analysis was used to analyze data. Specifically, the program MULRØ5 of the Division of Educational Research Services of the University of Alberta was used.

Initially, data cards were prepared for all students who had completed all test instruments that had been administered for this study.

Both continuous and categorical variables were included in the study. The continuous variables composed of scores with an assumed underlying distribution with any score possible and equal size units included IQ scores, reflective intelligence scores (SK 6 (I) and SK 6 (II)), field-dependence-independence scores (Cf-1), mathematics achievement scores, concept attainment scores and problem solving scores. The categorical variables in which a subject belongs to one and only one group included sex of student and instructional strategy grouping.

The underlying assumption of the multiple linear regression approach is that a functional relationship exists between the dependent variable (Y) and the independent variables (X_i) such that $Y = f(X_1,\ldots,X_n)$. This relationship is linear and additive giving the model the form

$$Y = A_oU + A_1X_1 + A_2X_2 + \ldots + A_nX_n + E$$

Where Y is the dependent variable
$X_1, X_2, \ldots, X_n$ are the independent predictor variables
U is a unit vector
A_0 is a constant for all subjects
$A_1, A_2, \ldots, A_n$ are regression weights

And E is the error term allowing for the possibility that Y may not be predictable.

If all the X_i's are independent, the full model has N + 1 degrees of freedom. That is, there are N + 1 independent predictors in the model. To investigate the contribution made by any single predictor, a restricted model incorporates the null hypotheses of no contribution for that particular X. Its coefficient attains the value zero.

For example, if the predictive contribution of X_1 is to be established, then $A_1 = 0$.

$Y = A_0U + A_1X_1 + A_2X_2 + \ldots + A_nX_n$ would be the full model.

$Y = A_0U + A_2X_2 + \ldots + A_nX_n$ would be the restricted model.

An F-test is used to compare the squared-multiple-correlations (SMC) calculated for each model. This F-test is defined as follows:

$$F = \frac{(R_1^2 - R_2^2)/(df_1 - df_2)}{(1 - R_1^2)/(N - df_1)}$$

Where R_1^2 and R_2^2 is the SMC's for the full and restricted models
df_1 and df_2 refer to the degrees of freedom
N refers to the number of subjects

An interaction variable is one which is generated from other variables by obtaining the product of these variables.

In the present study if X_1 is the predictor vector for field-

dependence-independence score and X_2 and X_3 are predictor vectors for the student-centered and teacher-centered instructional strategies, then X_4 and X_5 can be defined as:

$$X_4 = X_1X_2$$

$$X_5 = X_1X_3$$

where X_4 and X_5 represent the interactions of field-dependence-independence with instructional strategy. Inclusion of interaction terms in the regression model accounts for instructional variation.

The analyses of Learning Environment Inventory Scores to determine if students in the student-centered strategy perceived their learning environment as different from students in the teacher-centered strategy on any of the 15 scales was carried out using analyses of variance among scores. The program ANOV 16 was utilized for this purpose. To determine if overall differences in environment perceptions occurred, multivariate analysis of variance was carried out utilizing the program MULV Ø8.

Necessary correlations among variables were Pearson-Product Moment correlations derived using the program DEST Ø2.

CHAPTER IV

RESULTS OF THE STUDY

I. INTRODUCTION

The purpose of this study was to investigate the relationship between Witkin's cognitive style dimension of field-dependence-independence and mathematics achievement and its components of concept attainment and problem solving. The investigation incorporated both student-centered and teacher-centered instructional strategies. To determine how students' perceived their instructional strategies, the Learning Environment Inventory was administered.

The first section of this Chapter presents a data analysis of students' perceptions of their learning environment on each of the fifteen scales of the LEI.

The second section of this Chapter presents a data analysis specific to the hypotheses of the study.

II. LEARNING ENVIRONMENT ANALYSIS

The Learning Environment Inventory was administered to each student at the end of the instructional period for the study. It consists of 15 scales designed to reflect student perceptions of the structural and social characteristics of their environment. It was used in this study to determine if students in the student-centered strategy perceived their environment as different from students in the teacher-centered strategy. The sample for the analysis consisted of 211 students of which 101 were in a student-centered strategy and 110 were in a teacher-centered strategy. Table III lists the mean subscale scores for each of the

TABLE III

LEARNING ENVIRONMENT SUBSCALE MEAN SCORES FOR EACH INSTRUCTIONAL STRATEGY

		MEAN SCORES	
	Subscale	Student-Centered	Teacher-Centered
1.	Cohesiveness	14.881	14.746
2.	Diversity	14.228	14.955
3.	Formality	15.753	14.991
4.	Speed	16.792	16.855
5.	Environment	16.337	17.373
6.	Friction	16.386	15.636
7.	Goal Direction	16.426	16.518
8.	Favoritism	18.901	19.055
9.	Cliqueness	15.663	15.464
10.	Satisfaction	17.366	18.309
11.	Disorganization	19.218	19.000
12.	Difficulty	17.594	17.236
13.	Apathy	18.515	17.945
14.	Democratic	17.782	18.336
15.	Competitiveness	17.297	16.673

Note: Maximum subscale score = 28; minimum =7

instructional strategies.

Multivariate analysis of variance was used to determine if students in the student-centered instructional strategy perceived their environment as different from students in the teacher-centered instructional strategy. A comparison of the student-centered and teacher-centered composite vectors formed from the 15 subscale means on the Learning Environment Inventory yielded a F-ratio of 2.43 which was significant. Thus, the students in the student-centered strategy perceived their learning environment as significantly different from the students in the teacher-centered strategy. Table IV contains the analyses of the composite mean vectors for the student-centered and teacher-centered groups.

TABLE IV

ANALYSIS OF THE COMPOSITE MEAN VECTORS OF ENVIRONMENTAL PERCEPTIONS FOR THE STUDENT-CENTERED AND TEACHER-CENTERED GROUPS

DF_1	DF_2	F-RATIO	PROBABILITY LEVEL
15	195	2.43	0.003

To determine on which subscales the significant differences occurred, an analysis of the learning environment subscale scores of the student-centered and teacher-centered instructional groups was carried out.

The results of this subscale analysis follows.

1. Cohesiveness

Interactions among individuals for a period of time produces a feeling of intimacy or cohesiveness. This subscale is designed to measure students' perceptions of their membership or non-membership in the class group. Class cohesiveness relates to learning according to the goal direction of the class.

Out of a maximum possible subscale score of 28, the cohesiveness subscale mean score for the student-centered group was 14.881 and was 14.746 for the teacher-centered group.

An analysis of variance of the cohesiveness subscale scores of the student-centered and teacher-centered groups yielded a F-ratio of 0.14 which was not significant. Table V shows the analysis of variance for the student-centered and teacher-centered group scores of cohesiveness.

TABLE V

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP COHESIVENESS SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	0.96	0.14	0.71
Error	209	6.76		

2. Diversity

This subscale is designed to measure the students' perceptions of the extent to which the class provides for a diversity of student interests and activities. This scale has not shown a strong relationship to learning (Walberg, 1969).

Out of a maximum possible subscale score of 28, the Diversity subscale mean score for the student-centered group was 14.228, and was 14.955 for the teacher-centered group.

An analysis of variance of the Diversity subscale scores of the student-centered and teacher-centered groups yielded a F-ratio of 5.48 which was significant at the .05 level. Table VI shows the analysis of variance for the student-centered and teacher-centered group scores of diversity.

TABLE VI

ANALYSIS OF VARIANCE OF THE STUDENT-CENTERED AND TEACHER-CENTERED GROUP DIVERSITY SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	27.81	5.49	0.02
Error	209	5.07		

3. Formality

This subscale provides a measure of students' perceptions of the extent to which behavior within the class is guided by formal rules. This subscale does not appear to relate to common measures of learning.

Out of a maximum possible subscale score of 28, the Formality subscale mean score for the student-centered group was 15.753, and was 14.991 for the teacher-centered group.

An analysis of variance of the formality subscale scores of the student-centered and teacher-centered groups yielded a F-ratio of 5.67 which was significant at the .05 level. Table VII shows the analysis of variance for the student-centered and teacher-centered group scores of formality.

TABLE VII

ANALYSIS OF VARIANCE OF THE STUDENT-CENTERED AND TEACHER-CENTERED GROUP FORMALITY SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	30.54	5.67	0.02
Error	209	5.39		

4. Speed

The speed subscale measures the students perceptions of the extent of congruency between the students' desired and the actual rate of class learning. Mathematics classes are normally perceived as fast-paced, however, no consistent relationship is reported concerning learning.

Out of a maximum possible subscale score of 28, the Speed subscale mean score for the student-centered group was 16.792 and was 16.855 for the teacher-centered group.

An analysis of variance of the Speed subscale scores of the student-centered and teacher-centered groups yielded a F-ratio of 0.02 which was not significant. Table VIII shows the analysis of variance for the student-centered and teacher-centered group scores of speed.

TABLE VIII

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP FORMALITY SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	0.20	0.02	0.88
Error	209	9.18		

5. Environment

The environment subscale was designed to determine students' perceptions of the suitability of their physical environment related to space and availability of materials, etc. It is generally positively correlated with measures of pupil learning (Walberg, 1969).

Out of a maximum possible subscale score of 28, the Environment subscale mean score for the student-centered group was 16.337 and was 17.373 for the teacher-centered group.

An analysis of variance of the environment subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 6.48 which was significant at the .05 level. Table IX shows the analysis of variance for the student-centered and teacher-centered group scores of environment.

TABLE IX

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP ENVIRONMENT SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	56.52	6.48	0.01
Error	209	8.72		

6. Friction

The friction subscale was designed to measure the students' perceptions of the amount of disagreement, tension and antagonism within the class. Friction is generally high in mathematics classes. In general, friction may be considered advantageous when learning criterion includes comprehension of complex concepts and demonstrable creativity (Anderson, 1970).

Out of a maximum possible subscale score of 28, the Friction subscale mean score for the student-centered group was 16.386, and was 15.636 for the teacher-centered group.

An analysis of variance of the friction subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 3.72 which was significant at the .05 level. Table X shows the analysis of variance for the student-centered and teacher-centered group scores of friction.

TABLE X

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP FRICTION SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	29.60	3.72	0.05
Error	209	7.96		

7. Goal Direction

The goal direction subscale was designed to measure students' perceptions of the class's recognition of expected goals and their acceptance by the class as a group. Generally, a highly goal directed class will reach its goals more often than in classes where goals are unspecified. This premise underlies the behavioral objective movement.

Out of a maximum possible subscale score of 28, the Goal Direction subscale mean score for the student-centered group was 16.426, and was 16.518 for the teacher-centered group.

An analysis of variance of the goal direction subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 0.06 which was not significant. Table XI shows the analysis of variance for the student-centered and teacher-centered group scores of goal direction.

TABLE XI

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP GOAL DIRECTION SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	0.45	0.06	0.80
Error	209	7.23		

8. Favoritism

This subscale was designed to give an indication of the students' perception of self-concept in relation to the class. It is essentially a measure of negative effect. Relationships with learning criteria are generally inconsistent.

Out of a maximum possible subscale score of 28, the Favoritism subscale mean score for the student-centered group was 18.901, and was 19.055 for the teacher-centered group.

An analysis of variance of the favoritism subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 0.09 which was not significant. Table XII shows the analysis of variance for the student-centered and teacher-centered group scores of favoritism.

TABLE XII

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP FAVORITISM SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	1.25	0.09	0.76
Error	209	13.88		

9. Cliqueness

This subscale was designed to measure the students' perceptions of the formation of subgroups within the class. These subgroups offer membership and protection for those who are failures in the group at large. In many cases they are a source of hostility and provide norms which lead to less than optimal productivity.

Out of a maximum possible subscale score of 28, the Cliqueness subscale mean score for the student-centered group was 15.663, and was 15.464 for the teacher-centered group.

An analysis of variance of the cliqueness subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 0.24 which was not significant. Table XIII shows the analysis of variance for the student-centered and teacher-centered group scores of cliqueness.

TABLE XIII

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP CLIQUENESS SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	2.10	0.24	0.63
Error	209	8.87		

10. Satisfaction

The satisfaction subscale was designed to determine the extent to which students like or dislike their class. Satisfaction can be expected to positively correlate with learning criteria.

Out of a maximum possible subscale score of 28, the Satisfaction subscale mean score for the student-centered group was 17.366, and was 18.309 for the teacher-centered group.

An analysis of variance of the satisfaction subscale scores of the student-centered and teacher-centered groups yielded a F-ratio of 6.36 which was significant at the 0.05 level. Table XIV shows the analysis of variance for the student-centered and teacher-centered group scores of satisfaction.

TABLE XIV

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP SATISFACTION SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	46.75	6.36	0.01
Error	209	7.35		

11. Disorganization

This subscale measures the students' perceptions of the extent of disorganization within the class. Disorganization is subject related and perceived as very high for mathematics classes. A consistent relationship shows that high disorganization leads to reduced pupil learning.

Out of a maximum possible subscale score of 28, the Disorganization subscale mean score for the student-centered group was 19.218, and was 19.000 for the teacher-centered group.

An analysis of variance of the Disorganization subscale scores of the student-centered and teacher-centered group yielded a F-ratio of 0.25 which was not significant. Table XV shows the analysis of variance for the student-centered and teacher-centered group scores of Disorganization.

TABLE XV

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP DISORGANIZATION SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	2.50	0.25	0.62
Error	209	10.07		

12. Difficulty

The Difficulty subscale measures the students' perceptions of their relative difficulty within a class. Students generally perceive mathematics classes as difficult but tend to learn most in classes perceived as difficult (Walberg, 1969).

Out of a maximum possible subscale score of 28, the Difficulty subscale mean score for the student-centered group was 17.594, and was 17.236 for the teacher-centered group.

An analysis of variance of the Difficulty subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 1.13 which was not significant. Table XVI shows the analysis of variance for the student-centered and teacher-centered group scores of Difficulty.

TABLE XVI

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP DIFFICULTY SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	6.73	1.13	0.29
Error	209	5.95		

13. Apathy

This subscale was designed to complement the cohesiveness subscale. It measures the students' perceptions of their affinity with class activities.

Out of a maximum possible subscale score of 28, the Apathy subscale mean score for the student-centered group was 18.515, and was 17.945 for the teacher-centered group.

An analysis of variance of the Apathy subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 1.83 which was not significant. Table XVII shows the analysis of variance for the student-centered and teacher-centered group scores of Apathy.

TABLE XVII

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP APATHY SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	17.06	1.83	0.18
Error	209	9.32		

14. Democratic

The Democratic subscale was designed to measure students' perceptions of the extent to which democratic procedures were used in the classroom. This scale does not relate significantly to pupil learning (Walberg, 1969).

Out of a maximum possible subscale score of 28, the Democratic subscale mean score for the student-centered group was 17.782, and was 18.336 for the teacher-centered group.

An analysis of variance of the Democratic subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 1.93 which was not significant. Table XVIII shows the analysis of variance for the student-centered and teacher-centered group scores of Democracy.

TABLE XVIII

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP DEMOCRACY SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	16.13	1.93	0.17
Error	209	8.37		

15. Competitiveness

The Competitiveness subscale was designed to measure students' perceptions of the extent of competition within a class. Thus far, it has been found to be unrelated to any learning criteria but correlates negatively with the proportion of girls in a class.

Out of a maximum possible subscale score of 28, the Competitiveness subscale mean score for the student-centered group was 17.297, and was 16.673 for the teacher-centered group.

An analysis of variance of the Competitiveness subscale scores for the student-centered and teacher-centered groups yielded a F-ratio of 2.08 which was not significant. Table XIX shows the analysis of variance for the student-centered and teacher-centered group scores of Competitiveness.

TABLE XIX

ANALYSIS OF VARIANCE OF STUDENT-CENTERED AND TEACHER-CENTERED GROUP COMPETITIVENESS SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	20.52	2.09	0.15
Error	209	9.84		

Summary

To determine if students in the student-centered and teacher-centered instructional strategies perceived their environments as different, a comparison of the vectors formed from the subscale mean scores on the Learning Environment Inventory was carried out. The analysis yielded a significant difference ($p \leq .05$) in students' perceptions of their overall environment.

On the fifteen subscales of the Learning Environment Inventory the students in the student-centered instructional strategy perceived their learning environment as significantly different ($p \leq .05$) from students in the teacher-centered strategy on five of the subscales. The students in the student-centered strategy perceived their environment as having significantly less Diversity and Satisfaction, but having significantly more Friction and Formality. They also perceived their physical environment as significantly less pleasing than did students in the teacher-centered instructional strategy.

III. HYPOTHESES DATA ANALYSES

The major concern of this study was to determine the relationship between the cognitive style dimension of field-dependence-independence and mathematics achievement and its components of concept attainment and problem solving. This relationship was investigated for instructional interactions using both student-centered and teacher-centered instructional strategies.

IQ and Reflective Intelligence were used as covariates in order to partial their predictive effect from field-dependence-independence. Sex-related differences were proposed in the theory for both mathematics achievement and field-dependence-independence. An analysis in terms of sex related differences was included.

The analysis of data and the findings of the study pertinent to the hypotheses follows.

Hypothesis One

There is no significant relationship between general ability, reflective intelligence and field-dependence-independence.

Results. To determine if any significant relationship existed between general ability as a Lorge-Thorndike composite IQ measure, reflective intelligence as measured by the Sk 6(I) and (II), and field-dependence-independence as measured by the HFT, Pearson-Product Moment correlations were derived. All variables were significantly related at the 0.001 level of significance Table XX gives the correlation matrix for the variables of concern.

TABLE XX

PEARSON-PRODUCT-MOMENT CORRELATIONS, MEANS AND STANDARD DEVIATIONS FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE, FIELD-DEPENDENCE-INDEPENDENCE, MATHEMATICS ACHIEVEMENT, CONCEPT ATTAINMENT AND PROBLEM SOLVING

	IQ	SK6(I)	SK6(II)	HFT	MATH	CON.	PROB.
IQ	1.000						
SK 6(I)	0.470*	1.000					
SK 6(II)	0.536	0.515	1.000				
HFT	0.375	0.312	0.301	1.000			
MATH. ACH.	0.582	0.452	0.443	0.314	1.000		
CONCEPTS	0.554	0.409	0.367	0.282	0.874	1.000	
PROBLEM SOL.	0.430	0.359	0.359	0.251	0.828	0.452	1.000
MEANS	104.208	19.790	14.621	9.565	12.910	9.915	2.994
STD. DEV.	13.094	5.451	7.656	2.345	4.363	2.680	2.318

*$P \leqslant .001$ for all correlations

Conclusion. On the basis of these results, Hypothesis One was rejected. A significant relationship ($p \leq .001$) existed between general ability, reflective intelligence and field-dependence-independence.

Hypothesis Two

Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores.

Results. To determine if any significant predictive relationship existed between field-dependence-independence scores and mathematics achievement and its components of concept attainment and problem solving, Pearson-Product Moment correlations were determined. A significant relationship ($p \leq .001$) existed for all variables. Table XX gives the correlations matrix for these variables.

In a predictive sense, regression model 04 yields a R^2 for field-dependence-independence predicting mathematics achievement of 0.09847. Thus, field-dependence-independence can singly account for about 10% of the variance in mathematics achievement scores.

Regression model 05 to determine the ability of field-dependence-independence to predict concept attainment scores yields a R^2 of 0.07949. Thus, field-dependence-independence can singly account for about 8% of the variance in concept attainment.

Regression model 06 to determine the ability of field-dependence-independence to predict problem solving scores yields a R^2 of 0.0630. Thus, field-dependence-independence can singly account for about 6% of

the variance in problem solving scores.

Table XXX contains a list of variables associated with the models. Table XXXI contains the list of models and the associated R^2 and regression weights. (See Appendix G).

Conclusion. On the basis of these results, Hypothesis Two was rejected. A significant relationship ($p \leqslant .001$) existed between field-dependence-independence, mathematics achievement, concept attainment and problem solving.

It must be cautioned that rejection is on the basis of group prediction of mathematics achievement, concept attainment and problem solving scores from field-dependence-independence scores.

Hypothesis Three

Field-dependence-independence will not be a significant predictor of mathematics achievement, concept attainment, or problem solving scores after general ability, reflective intelligence, or general ability and reflective intelligence is accounted for.

Results. Multiple linear regression analysis was used to determine if field-dependence-independence is a significant predictor of mathematics achievement, concept attainment and problem solving scores after accounting for general ability, reflective intelligence, or general ability and reflective intelligence.

Models 10 and 28 were compared to determine if field-dependence-independence is a significant predictor of mathematics achievement after general ability (IQ). The comparison yielded a F-ratio of 2.85 which

was not significant at the 0.05 level.

Models 13 and 31 were compared to determine if field-dependence-independence is a significant predictor of mathematics achievement after accounting for reflective intelligence (SK 6(I) & (II)). The comparison yielded a F-ratio of 4.89 which was significant at the .05 level.

Models 07 and 01 were compared to determine if field-dependence-independence is a significant predictor of mathematics achievement after accounting for general ability and reflective intelligence. The comparison yielded a F-ratio of 1.15 which was not significant at the 0.05 level.

Table XXI contains the results of these model comparisons.

TABLE XXI

TESTS OF THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT MATHEMATICS ACHIEVEMENT AFTER ACCOUNTING FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE, AND GENERAL ABILITY AND REFLECTIVE INTELLIGENCE

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
10	1	0.34922	2.84	0.09
28	175	0.33863		
13	1	0.28471	4.89	0.03
31	174	0.26459		
7	1	0.39174	1.15	0.28
1	172	0.38766		

Models 11 and 29 were compared to determine if field-dependence-independence is a significant predictor of concept attainment after accounting for general ability. The comparison yielded a F-ratio of 1.63 which was not significant at the 0.05 level.

Models 14 and 32 were compared to determine if field-dependence-independence is a significant predictor of concept attainment after accounting for reflective intelligence. The comparison yielded a F-ratio of 3.95 which was significant at the 0.05 level.

Models 8 and 2 were compared to determine if field-dependence-independence is a significant predictor of concept attainment after accounting for both general ability and reflective intelligence. The comparison yielded a F-ratio of 0.68 which was not significant at the 0.05 level.

Table XXII contains the results of the comparisons between these models.

TABLE XXII

TESTS OF THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT CONCEPT ATTAINMENT AFTER ACCOUNTING FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE, AND GENERAL ABILITY AND REFLECTIVE INTELLIGENCE

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
11	1	0.31304	1.63	0.20
29	175	0.30665		
14	1	0.21835	3.95	0.04
32	174	0.20063		
8	1	0.33832	0.68	0.41
2	172	0.33572		

Models 12 and 30 were compared to determine if field-dependence-independence is a significant predictor of problem solving scores after accounting for general ability. The comparison yielded a F-ratio of 2.04 which was not significant at the 0.05 level.

Models 15 and 33 were compared to determine if field-dependence-independence is a significant predictor of problem solving scores after accounting for reflective intelligence. The comparison yielded a F-ratio of 2.48 which was not significant at the 0.05 level.

Models 9 and 3 were compared to determine if field-dependence-independence is a significant predictor of problem solving scores after accounting for both general ability and reflective intelligence. The comparison yielded a F-ratio of 0.77 which was not significant at the 0.05 level.

Table XXIII contains the results of the comparisons between these models.

TABLE XXIII

TESTS OF THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT PROBLEM SOLVING SCORES AFTER ACCOUNTING FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE, AND GENERAL ABILITY AND REFLECTIVE INTELLIGENCE.

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
12	1	0.19414	2.04	0.15
20	175	0.18477		
15	1	0.19750	2.48	0.12
33	174	0.18607		
9	1	0.23796	0.77	0.38
3	172	0.23454		

Conclusion. On the basis of the results, Hypothesis Three was rejected for the cases of field-dependence-independence being a significant predictor of mathematics achievement and concept attainment after accounting for reflective intelligence.

Field-dependence-independence was not a significant predictor of mathematics achievement, concept attainment or problem solving scores after accounting for general ability or both general ability and reflective intelligence. Nor was it a significant predictor of problem solving scores after accounting for reflective intelligence.

Hypothesis Four

Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores in either a student-centered or teacher-centered instructional strategy.

Results. Multiple linear regression analysis was used to determine if field-dependence-independence is a significant predictor of mathematics achievement and its components in the different instructional strategies. The test of the hypothesis at this point is to determine if there was any interaction between field-dependence-independence and the teacher-centered or student-centered instructional strategies. That is, it is a determination of instructional variation.

Models 16 and 04 were compared to determine if there was any instructional variation in the ability of field-dependence-independence to predict mathematics achievement. The comparison yielded a F-ratio

of 0.00 which was not significant.

Models 17 and 5 were compared to determine if there was any instructional variation in the ability of field-dependence-independence to predict concept attainment scores. The comparison yielded a F-ratio of 0.00 which was not significant.

Models 18 and 6 were compared to determine any instructional variation in the ability of field-dependence-independence to predict problem solving scores. The comparison yielded a F-ratio of 0.24 which was not significant.

Table XXIV contains the results of the comparisons of these models.

TABLE XXIV

TESTS OF INSTRUCTIONAL VARIATION IN THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT MATHEMATICS ACHIEVEMENT, CONCEPT ATTAINMENT AND PROBLEM SOLVING SCORES

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
16	1	0.09753	0.00*	1.00
4	175	0.09847		
17	1	0.07745	0.00*	1.00
5	175	0.07949		
18	1	0.06432	0.24	0.62
6	175	0.06304		

* calculation gives negative value.

Conclusion. On the basis of these results, Hypothesis Four was not rejected. There was no instructional interactions with the ability of field-dependence-independence to predict mathematics achievement scores,

concept attainment scores, or problem solving scores.

Hypothesis Five

Field-dependence-independence will not be a significant predictor of mathematics achievement scores, concept attainment scores, or problem solving scores in either a student-centered or a teacher-centered instructional strategy after general ability, reflective intelligence, or general ability and reflective intelligence is accounted for.

Results. Multiple linear regression analysis was used to test for any instructional variation in the predictive ability of field-dependence-independence after accounting for general ability, reflective intelligence and their combination.

Models 22 and 10 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict mathematics achievement scores after accounting for general ability. The comparison yielded a F-ratio of 0.05 which was not significant.

Models 25 and 13 were compared to determine any instructional variation in the ability of field-dependence-independence to predict mathematics achievement scores after accounting for reflective intelligence. The comparison yielded a F-ratio of 0.39 which was not significant.

Models 19 and 07 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict mathematics achievement scores after accounting for both

general ability and reflective intelligence. The comparison yielded a F-ratio of 0.46 which was not significant.

Table XXV contains the results of the comparisons between these models.

TABLE XXV

TESTS OF INSTRUCTIONAL VARIATION IN THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT MATHEMATICS ACHIEVEMENT AFTER ACCOUNTING FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE, AND GENERAL ABILITY AND REFLECTIVE INTELLIGENCE

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
22	1	0.34939	0.05	0.83
10	174	0.34922		
25	2	0.28791	0.39	0.68
13	173	0.28471		
19	1	0.39337	0.46	0.50
7	172	0.39174		

Models 23 and 11 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict concept attainment scores after accounting for general ability. The comparison yielded a F-ratio of 0.06 which was not significant.

Models 26 and 14 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict concept attainment scores after accounting for reflective intelligence. The comparison yielded a F-ratio of 0.38 which was not significant.

Models 20 and 8 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict concept attainment scores after both general ability and reflective intelligence are accounted for. The comparison yielded a F-ratio of 0.48 which was not significant.

Table XXVI contains the results of the comparisons between these models.

TABLE XXVI

TESTS OF INSTRUCTIONAL VARIATION IN THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT CONCEPT ATTAINMENT SCORES AFTER ACCOUNTING FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE, AND GENERAL ABILITY AND REFLECTIVE INTELLIGENCE

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
23	1	0.31328	0.06	0.81
11	174	0.31304		
26	2	0.22172	0.38	0.69
14	173	0.21835		
20	1	0.34017	0.48	0.49
9	172	0.33832		

Models 24 and 12 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict problem solving scores after accounting for general ability. The comparison yielded a F-ratio of 0.17 which was not significant.

Models 27 and 15 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to

predict problem solving scores after accounting for reflective intelligence. The comparison yielded a F-ratio of 0.17 which was not significant.

Models 21 and 9 were compared to determine if any instructional variation occurred in the ability of field-dependence-independence to predict problem solving scores after accounting for both general ability and reflective intelligence. The comparison yielded a F-ratio of 0.19 which was not significant.

Table XXVII contains the results of the comparisons between these models.

TABLE XXVII

TESTS OF INSTRUCTIONAL VARIATION IN THE ABILITY OF FIELD-DEPENDENCE-INDEPENDENCE TO PREDICT PROBLEM SOLVING SCORES AFTER ACCOUNTING FOR GENERAL ABILITY, REFLECTIVE INTELLIGENCE AND GENERAL ABILITY AND REFLECTIVE INTELLIGENCE

MODEL NO.	DF	RSQ	F-RATIO	PROBABILITY LEVEL
24	1	0.19492	0.17	0.68
12	174	0.19414		
27	2	0.19910	0.17	0.84
15	173	0.19750		
21	1	0.23878	0.19	0.67
9	172	0.23796		

Conclusion. On the basis of these results, Hypothesis Five was not rejected. There was no significant instructional variation in the ability of field-dependence-independence to predict mathematics

achievement, concept attainment or problem solving scores after accounting for general ability, reflective intelligence and both general ability and reflective intelligence.

Hypothesis Six

There will be no significant difference in the mean mathematics achievement, concept attainment or problem solving scores of boys and girls.

Results. Analysis of variance was used to determine if any significant sex-related differences occurred in mathematics achievement, concept attainment or problem solving.

Analysis of the mathematics achievement scores yielded a F-ratio of 1.43 which was not significant at the 0.05 level.

Analysis of the concept attainment scores yielded a F-ratio of 2.02 which was not significant at the 0.05 level.

Analysis of the problem solving scores yielded a F-ratio of 0.31 which was not significant at the 0.05 level.

Table XXVIII contains the analysis of variance of sex-related differences in mathematics achievement, concept attainment and problem solving scores.

TABLE XXVIII

ANALYSIS OF VARIANCE OF SEX-RELATED DIFFERENCES IN MATHEMATICS ACHIEVEMENT, CONCEPT ATTAINMENT AND PROBLEM SOLVING SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	26.01	1.43	0.23
Error	175	18.23		
Group	1	14.50	2.02	0.16
Error	175	7.18		
Group	1	1.67	0.31	0.58
Error	175	5.42		

Conclusion. On the basis of these results, Hypothesis Six was not rejected. There were no significant differences in the mean mathematics achievement, concept attainment or problem solving scores of boys and girls.

Hypothesis Seven

There will be no significant difference in mean field-dependence-independence scores of boys and girls.

Results. Analysis of variance was used to determine if sex-related differences occurred in field-dependence-independence scores.

Analysis of the field-dependence-independence scores of males and females yielded a F-ratio of 0.00 which was not significant at the 0.05 level.

Table XXXIX contains the results of the analysis of variance of field-dependence-independence scores for males and females.

TABLE XXIX

ANALYSIS OF VARIANCE OF SEX-RELATED DIFFERENCES IN FIELD-DEPENDENCE-INDEPENDENCE SCORES

SOURCE	DF	MEAN SQUARE	F-RATIO	PROBABILITY LEVEL
Group	1	0.01	0.00	0.98
Error	175	26.33		

Conclusion. On the basis of these results, Hypothesis Seven was not rejected. There was no significant difference in the mean field-dependence-independence scores of boys and girls.

IV. SUMMARY

Analysis of students' perceptions of their instructional strategy yielded significant differences ($p \leq .05$) in overall strategy perceptions and on five of the fifteen subscales of the Learning Environment Inventory. These significant differences occurred on the Diversity, Satisfaction, Friction, Formality and Environment subscales.

Analysis of general ability as a composite Lorge Thorndike IQ score, reflective intelligence as measured by Skemp's SK 6(I) and (II)

and field-dependence-independence as measured by the Hidden Figures Test (Cf-1) yielded significant correlations ($p \leq .001$) between these variables. On this basis Hypothesis One, of no significant relationship between these variables, was rejected.

Analysis of field-dependence-independence and mathematics achievement, concept attainment and problem solving scores yielded significant correlations ($p \leq .001$) between these variables. Thus, field-dependence-independence was interpreted as having group predictive ability of mathematics achievement, concept attainment and problem solving scores. Thus, Hypothesis Two was rejected.

Field-dependence-independence proved to be a significant predictor of mathematics achievement and concept attainment scores after accounting for reflective intelligence. However, it was not a significant predictor of problem solving scores after accounting for reflective intelligence. After accounting for general ability or for both general ability and reflective intelligence, field-dependence-independence was not a significant predictor of mathematics achievement, concept attainment or problem solving scores. Thus, on this basis Hypothesis Three was rejected for the first case and not rejected for all others.

There was no significant difference in the ability of field-dependence-independence to predict mathematics achievement, concept attainment, or problem solving scores in either a student-centered or teacher-centered instructional strategy. There was no instructional variation after general ability, reflective intelligence, or both general ability and reflective intelligence were accounted for. On

the basis of these results, Hypothesis Four and Hypothesis Five were not rejected.

Analysis of differences in the mean scores of mathematics achievement, concept attainment, problem solving, and field-dependence-independence yielded no significant sex-related differences. On the basis of these results, Hypothesis Six and Hypothesis Seven were not rejected.

CHAPTER V

SUMMARY, DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

I. SUMMARY OF THE INVESTIGATION

The present study was designed to investigate the relationship between Witkin's cognitive style dimension of field-dependence-independence and mathematics achievement and its components of concept attainment and problem solving. The investigation was carried out using both student-centered and teacher-centered instructional strategies in order to determine if any instructional variation occurred in the investigated relationship. General ability and reflective intelligence were used as covariates to determine their relationship to field-dependence-independence and to establish any ability of field-dependence-independence to predict mathematics achievement, concept attainment and problem solving scores after accounting for these variables.

In order to gather the necessary data, a sample of grade eight students and various instruments were employed.

Sample and Procedures

A sample of 177 grade eight students consisting of 97 males and 80 females was utilized for analyses purposes. The sample was drawn from the complete grade eight population of two junior high schools under the jurisdiction of the Edmonton Separate School Board. The total population consisted of 213 students divided between the two schools. Each school contained four grade eight classes with mathematics instruction being given by two teachers in each school. Thus, each teacher taught two classes. One class used a teacher-centered

instructional strategy and the other used a student-centered instructional strategy. Thus, four student-centered and four teacher-centered classes were employed for the study.

The schools were chosen by School Board personnel to be representative of the Board's total population. Students were randomly assigned to classes at the beginning of the year with attention given only to obtaining a class balance by sex.

Materials were developed covering the topics of Linear, Area and Angular Measurement which composed part of the beginning unit of the grade eight mathematics program. These materials were developed to require active student involvement in the learning process and paralleled the regular measurement unit. These materials were used for the student-centered instructional strategy. The teacher-centered instructional strategy was 'traditional' in nature but covered the same basic measurement concepts. Teachers were in-serviced as to their expected role and the procedures in each strategy.

The investigation commenced at the beginning of the school year and was of approximately four weeks duration.

Instruments

A Learning Environment Inventory consisting of 15 subscales and measuring students' perceptions of the social and structural characteristics of their learning environment was employed to determine if students in the student-centered instructional strategy perceived their environment as different from students in the teacher-centered instructional strategy.

The Lorge-Thorndike composite IQ score was obtained from students' records and used as a measure of general ability. The Lorge-Thorndike is administered to all students as part of the assessment program of the Edmonton Separate School Board.

Skemp's SK 6(I) of Operations Formation and SK 6(II) of Reflective Action With Operations was used as a measure of reflective intelligence. These instruments were investigator administered to the total population one week after the investigation had begun.

The Hidden Figures Test (Cf-1) was used as a measure of field-dependence-independence. It was administered by the investigator to the total population immediately prior to the investigation.

A mathematics achievement test with a concept attainment and problem solving component was devised by the investigator and used in the study. It tested the topics of Linear, Area and Angular Measurement which were those being dealt with during the study. The mathematics achievement test was administered to the total population at the end of the measurement unit and study which was of four weeks duration. Test-retest reliability coefficients for the test are as follows: mathematics achievement total score, 0.93; concept attainment component, 0.85; and problem solving component, 0.93.

Interviews were conducted with a subsample of two students from each class chosen according to a high or low score on the Hidden Figures Test. An interview protocal questionnaire (Appendix F) was devised and used to glean information from the students concerning their perceptions of classroom procedures, general mathematics ability and attitude, and

problem solving style. This data was gathered for its possible benefit in data interpretation.

The Learning Environment Inventory data was analyzed using analysis of variance and utilized the ANOV 16 Program of the Division of Educational Research Services (DERS), Faculty of Education at the University of Alberta. Multivariate analysis was used to determine overall environmental difference and utilized the Program MULV 08. Multiple linear regression analysis was used to determine the ability of field-dependence-independence to predict mathematics ability. The program MULR 05 of DERS was utilized. Correlations required were Pearson-Product Moment correlations and were determined using the DEST 02 Program of DERS.

Conclusion

A summary of the findings will be presented as follows: firstly, on the basis of the learning environment analysis; and secondly, on the basis of testing the hypotheses.

Analysis of students' perceptions of their instructional strategy yielded significant differences ($p \leq .05$) overall and on five of the fifteen subscales of the Learning Environment Inventory. These significant differences occurred on the Diversity, Satisfaction, Friction, Formality and Environment subscales. The students in the student-centered instructional strategy perceived their environment as having significantly less diversity and satisfaction and more friction and formality. As well, the students in the student-centered strategy were significantly less satisfied with their physical environment than students in the teacher-centered instructional strategy.

Analysis of general ability (Lorge-Thorndike Composite IQ Score), reflective intelligence (SK 6(I) and (II)), and field-dependence-independence (Hidden Figures Test, Cf-1) scores yielded significant correlations ($p \leq .001$) between these variables. On the basis of these results Hypothesis One, of no significant relationship between these variables, was rejected.

Analysis of field-dependence-independence and mathematics achievement, concept attainment and problem solving scores yielded significant correlations ($p \leq .001$) between these variables. Thus, field-dependence-independence was interpreted as having group predictive ability of mathematics achievement, concept attainment and problem solving scores. Hypothesis Two was rejected.

Field-dependence-independence proved to be a significant predictor of mathematics achievement and concept attainment scores but not of problem solving scores after accounting for reflective intelligence. However, after accounting for general ability or for both general ability and reflective intelligence, field-dependence-independence was not a significant predictor of mathematics achievement, concept attainment or problem solving scores. Thus, Hypothesis Three was rejected for the first and second cases and not rejected for all others.

There was no significant difference in the ability of field-dependence-independence to predict mathematics achievement, concept attainment or problem solving scores in either a student-centered or teacher-centered instructional strategy. As well, there was no instructional strategy variation after accounting for general ability,

reflective intelligence or both general ability and reflective intelligence. On the basis of these findings, Hypothesis Four and Hypothesis Five were not rejected.

Analysis of sex-related differences in the mean scores of mathematics achievement, concept attainment, problem solving and field-dependence-independence yielded no significant differences. Thus, on the basis of these results, Hypothesis Six and Hypothesis Seven were not rejected.

II. DISCUSSION AND IMPLICATIONS OF THE FINDINGS

The findings related to the instructional strategies indicated that students did in fact note differences in the strategies. However, instructional differences did not affect achievement nor were there any significant differences between treatments on any of the variables used in the study (see Table XXXII, Appendix H).

Interviews with a small sample of students indicated that preconceived notions of the style of mathematics instruction were prominent. In all cases, students indicated that mathematics instruction consisted of teacher presentation of a topic followed by a presentation of example questions related to the topic, followed by the setting of student questions. These preconceived notions of mathematics instruction are congruent to the teacher-centered or 'traditional' instructional procedures. The students in the student-centered strategy who were interviewed, noted that their instruction was different than their preconceived notions. However, they seemed to rationalize that measuring

was a logical way to learn measurement. In terms of preferred method of instruction, students generally agreed that the instruction they were involved in was suitable or indicated no other preferred method.

The student-centered group reacted adversely to their instructional strategy on the Diversity, Satisfaction, Environment, Friction and Formality subscales of the Learning Environment Inventory. In terms of the initial designing of the student-centered strategy, these adverse perceptions were not in the expected direction. It was expected that a strategy in which opportunity to investigate by measuring, discussing, hypothesizing and checking would dictate greater student involvement and would have greater Diversity, less Formality, be a more pleasing environment and thus may give greater Satisfaction. Students' perceptions did not show this to be the case. A knowledge of the students' preconceived notions of mathematics instruction indicates a likelihood that the adverse reaction may be due to the non-congruence in instruction received and instruction expected. That is, it may have been an adverse reaction to a change in instructional strategy rather than to the strategy itself.

The significant correlational relationship which was present between the predictor variables of field-dependence-independence, general ability and reflective intelligence, and the criterion variables of mathematics achievement, concept attainment and problem solving indicates that each is a significant single group predictor of the others. However, due to the high correlational relationship the predictive ability of any one predictor variable after accounting for any other is severely limited. As single predictors, however, IQ was best with reflective

intelligence second and then field-dependence-independence. This pattern occurred for all three criterion variables.

Field-dependence-independence was not a significant predictor of either mathematics achievement, concept attainment or problem solving scores after general ability was accounted for. As well, field-dependence-independence and general ability were significantly correlated. In a practical sense, where a measure of general ability is available, the benefit of a measure of field-dependence-independence is significantly reduced and thus questionable.

Indications from earlier research (Witkin et al., 1977; McLeod et al., 1978) of interactions between instructional strategies and cognitive style were not found in this study.

Since all variables, both predictor and criterion, were significantly related, it appears that each was tapping a single or group of identical component skills. One possibility is that spatial restructuring is the underlying component. The IQ, reflective intelligence and field-dependence-independence tests all include items requiring spatial restructuring ability. Measurement itself requires an individual to develop some mental picture of unit size for comparison purposes in estimating, analyzing and synthesizing underlying concepts to develop a systematized gestalt. These component abilities are factors which are characteristic of relative field-independence. Thus, it appears that the choice of unit for the study could have influenced the results.

Text materials used in this study as well as those used generally for mathematics instruction are developmentally logical and inherently

structured. Although this provision of structure should compensate for theorized lack of restructuring ability of field-dependent students, it seems that a field-independent student could more suitably progress through these materials and generally through mathematics topics and thus achieve more success from them. That is, mathematics may be field-independent characteristic.

The findings of no significant sex-related differences in either mathematics achievement, concept attainment, problem solving or field-dependence-independence contradicts earlier findings (Witkin et al., 1977; Glennon and Callahan, 1968). It appears that the increased concern with the role of the female in society in the past decade may in fact be influencing sex-related achievement patterns as is hypothesized by Maccoby and Jacklin (1974). However, since the sample for the study was mainly middle-class and urban, the sample may represent only a socially aware pocket of the larger population.

The following implications and indications can be interpreted from the results:

1. General ability (IQ), reflective intelligence and field-dependence-independence are all significant predictors of mathematics achievement, concept attainment and problem solving. General ability is a better predictor than reflective intelligence which is better than field-dependence-independence. This predictive ability decreases from overall mathematics achievement to problem solving.

2. Interactions between cognitive style and instructional strategies as was predicted by earlier research did not occur. However, these results may be topic related.

3. There were no sex-related differences in mathematics achievement, concept attainment, problem solving or field-dependence-independence scores. This may be due to either the increased concern for the female role in society or a reflection of the social values of a middle-class urban population and not a reflection of the general population.

III. RECOMMENDATIONS FOR FURTHER RESEARCH

The present study investigated the relationship between field-dependence-independence and mathematics achievement, concept attainment and problem solving in both student-centered and teacher-centered instructional strategies. The topics of Linear, Area and Angular Measurement constituted the mathematics instruction. Since measurement requires spatial reconstruction, it is hypothesized that the topic may have influenced the results.

It is recommended that a study similar to this one be conducted using various mathematics topics to determine if changing the topic will produce differing results.

The present study indicated that mathematics achievement and its components of concept attainment and problem solving may be field-independent characteristic. A study of the methods of structuring and analyzing of concepts and problems of field-dependent and field-independent students may provide evidence of some differing operating skills used by each. This could provide evidence of possible teachable skills to aid further achievement by the field-dependent student.

Evidence from the Learning Environment Inventory indicates adverse perceptions of the student-centered instructional strategy. These adverse perceptions were hypothesized to be due to change in instructional strategy. Since research indicates that the field-dependent student is more attentive to social referents and the field-independent student more attentive to structural referents (Witkin and Goodenough, 1977), an analysis of student responses to the LEI in terms of relative

field-independence may provide interesting results.

The finding of no sex-related differences in mathematics achievement, concept attainment, problem solving or field-dependence-independence may indicate a change in female achievement patterns. However, these results may be due to the use of an urban, middle-class, population in the study. Further research of sex-related differences using a more varied population is suggested.

Finally, it is recommended that research involving instructional strategies include the determining of students' perceptions of the strategy using either high inference measures such as the LEI, or sub-sample personal interviews with students, or both.

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A P P E N D I X A

SAMPLE ITEM

HIDDEN FIGURES TEST (Cf-1)

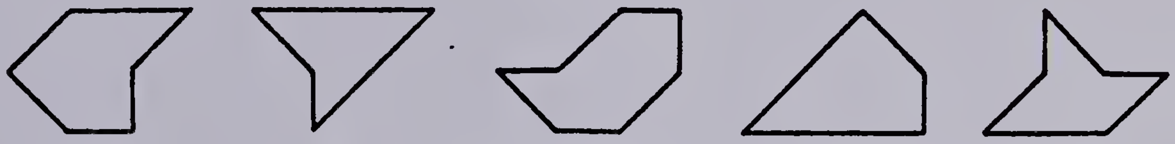
Name ____

HIDDEN FIGURES TEST — CF-1 (Rev.)

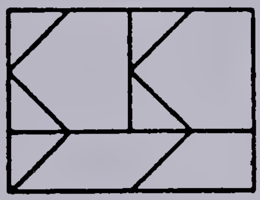
This is a test of your ability to tell which one of five simple figures can be found in a more complex pattern. At the top of each page in this test are five simple figures lettered A, B, C, D, and E. Beneath each row of figures is a page of patterns. Each pattern has a row of letters beneath it. Indicate your answer by putting an X through the letter of the figure which you find in the pattern.

NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

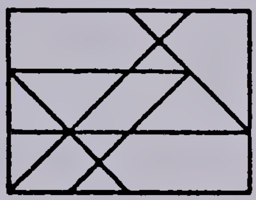
Now try these 2 examples.



A B C D E

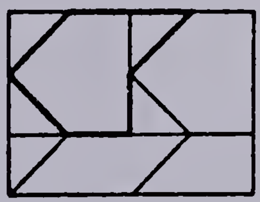
I 

A B C D E

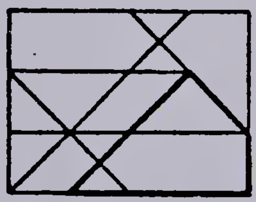
II 

A B C D E

The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

I 

X B C D E

II 

A B C X E

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

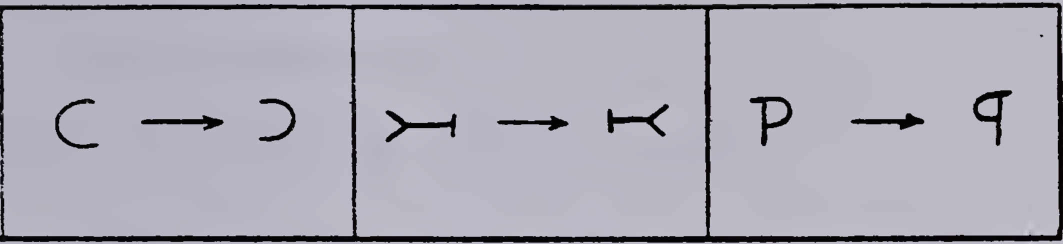
You will have 12 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

APPENDIX B

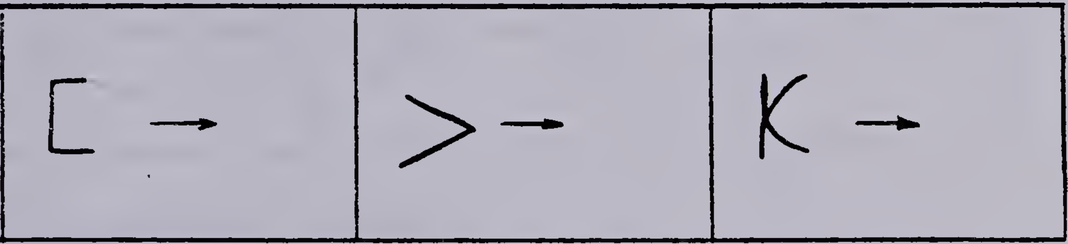
SKEMP'S TEST

SK 6(I) & (II)

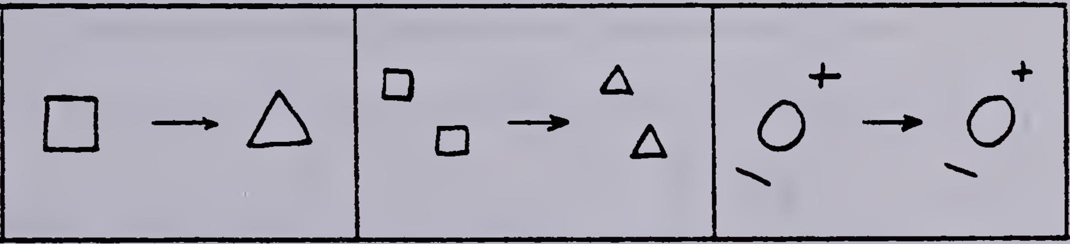
Operation 1	

In the above figures, the one on the left of each pair has been changed to the one on the right by means of the same simple operation. In other words, the above figures give three examples of a particular operation. You have to find out what the operation is, and then do the same operation to some other figures.

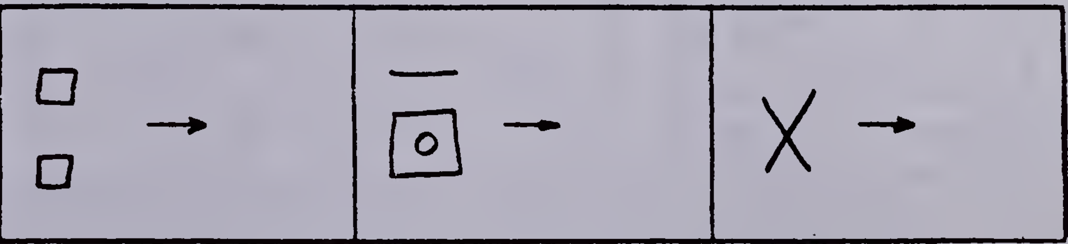
What is the operation? It is reversing from left to right. Do this on each of the figures below, and fill in the answers in the blank spaces. Check with the answers on the blackboard to make sure that you have understood.

Do Operation 1 on these.	

Here is a different operation:

Operation 2	

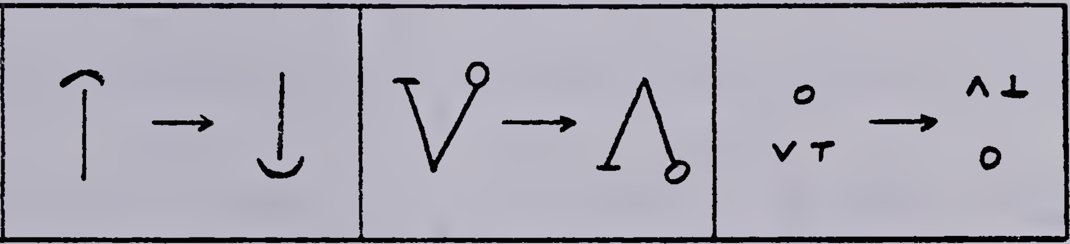
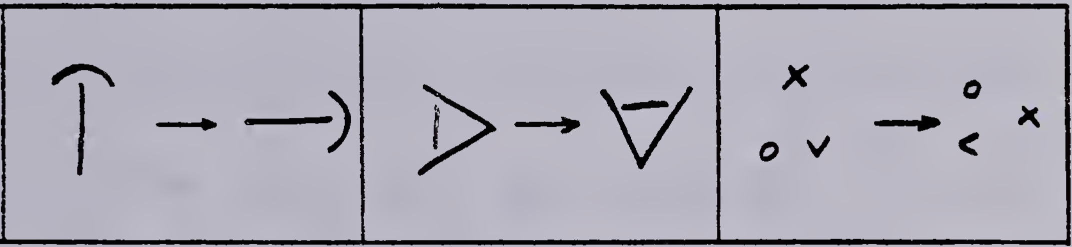
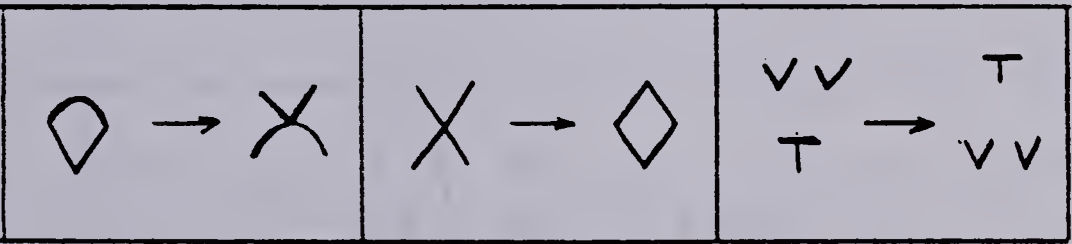
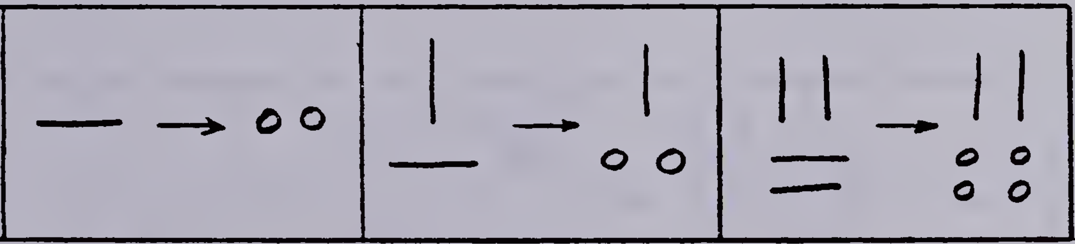
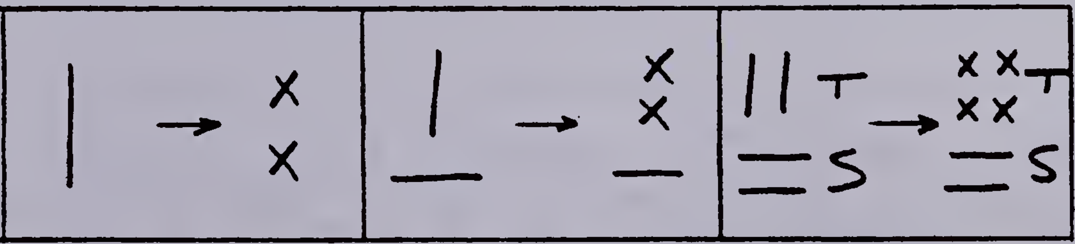
When you have found out what it is, do it on the figures below. Check with the answers on the board.

Do Operation 2 on these.	

SK6: DEMONSTRATION SHEET

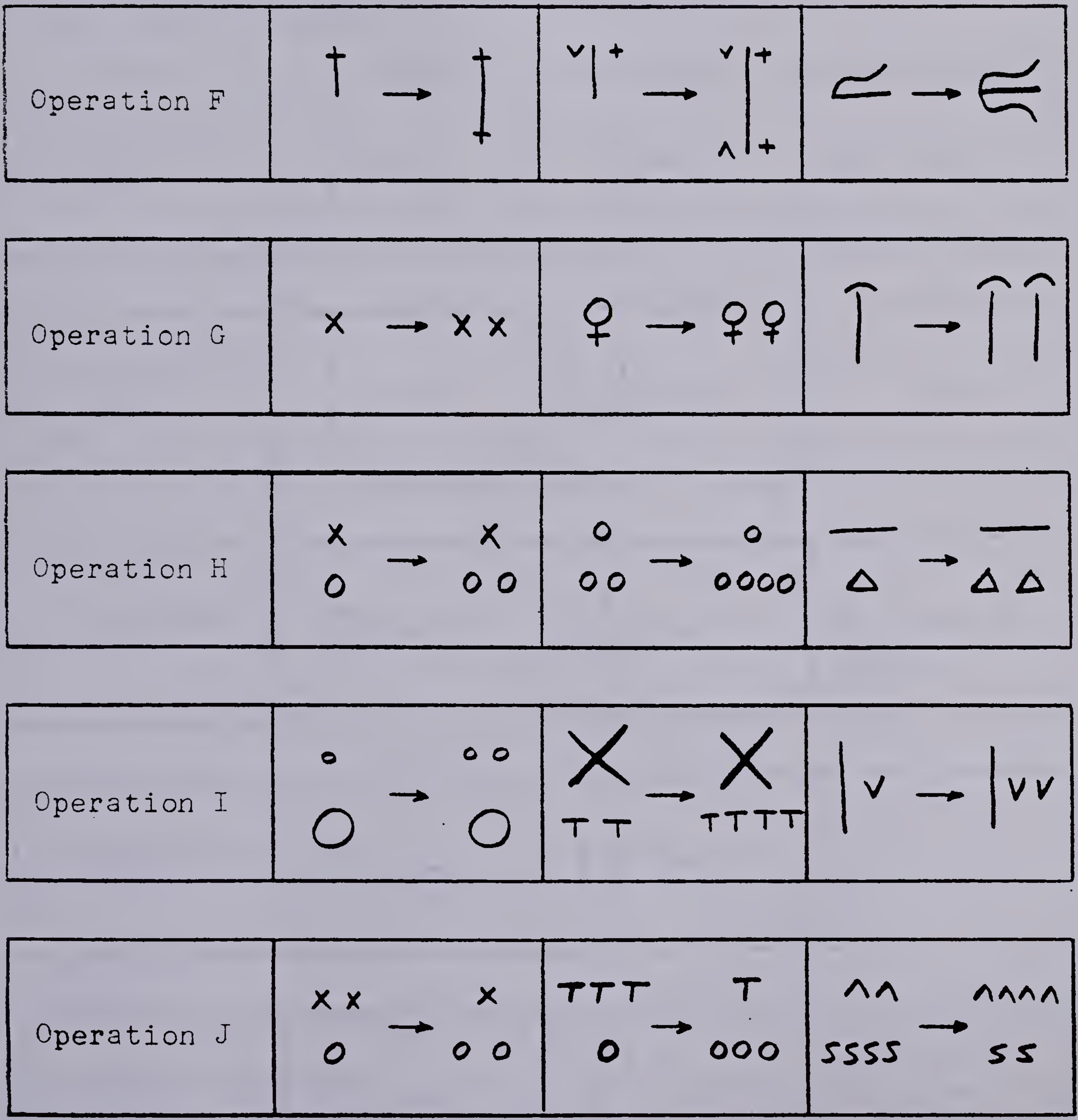
OPERATIONS A TO E

(OPERATIONS F TO J ARE ON THE NEXT PAGE)

Operation A	
Operation B	
Operation C	
Operation D	
Operation E	

SK6: DEMONSTRATION SHEET

OPERATIONS F TO J



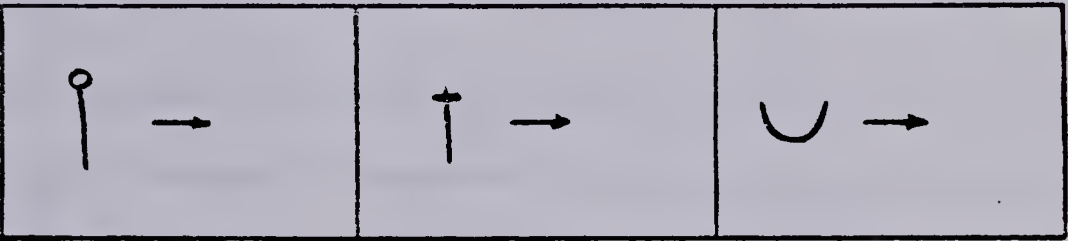
NAME .... SCHOOL ....
Last First Middle

AGE .... GRADE .... BOY GIRL DATE ....
Years (Circle One) Day Month Yr.

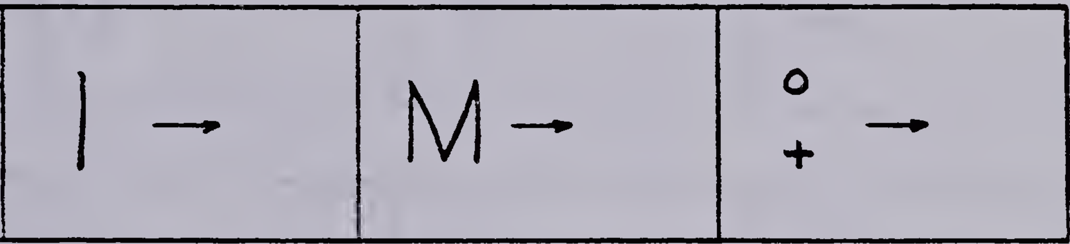
SK6: PART I

Find out the operations from the DEMONSTRATION SHEET, and fill in the answers in the blank spaces, just as you did on the PRACTICE SHEET.

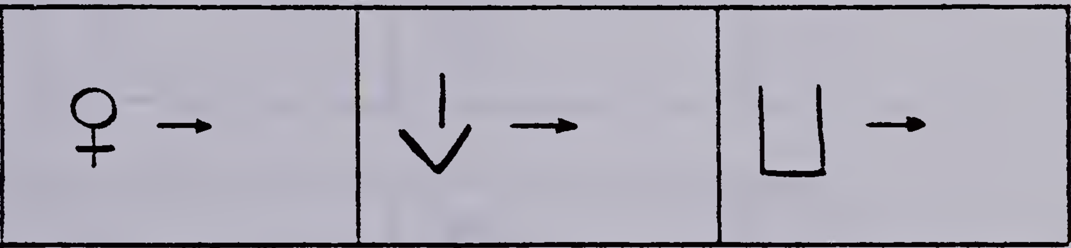
Do Operation A on these.



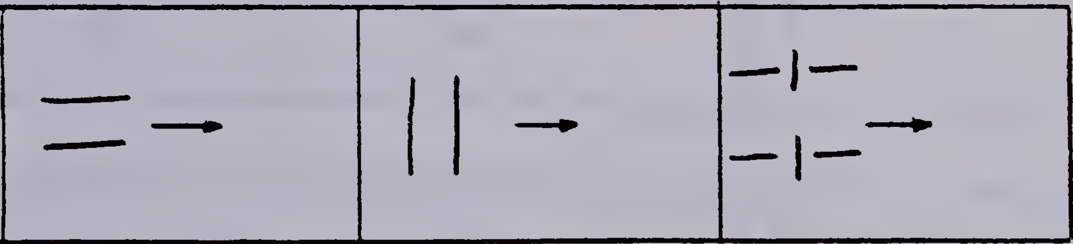
Do Operation B on these.



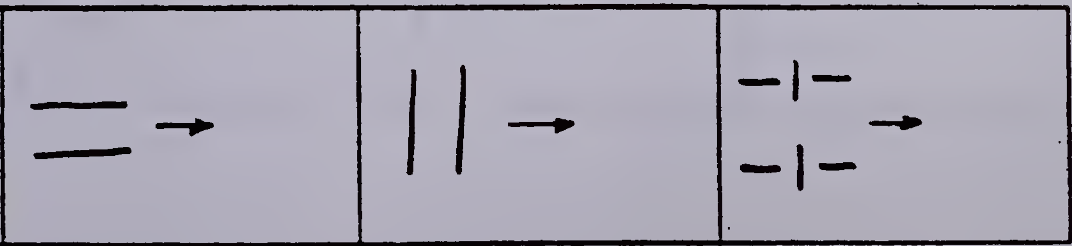
Do Operation C on these.



Do Operation D on these.

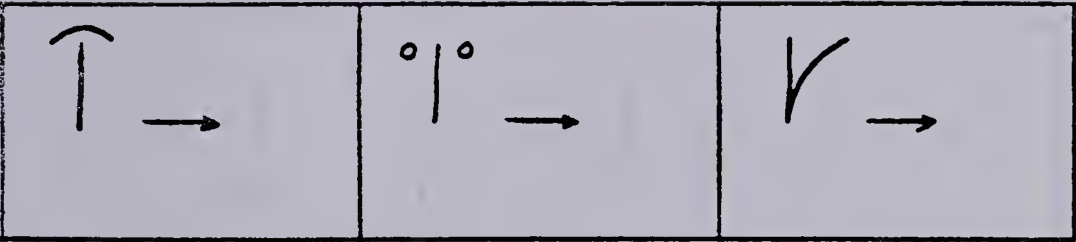
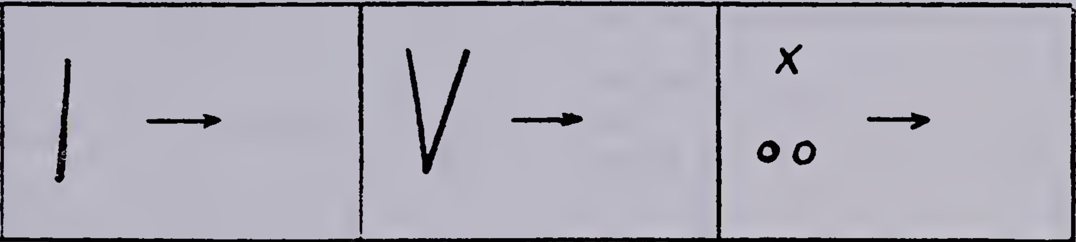
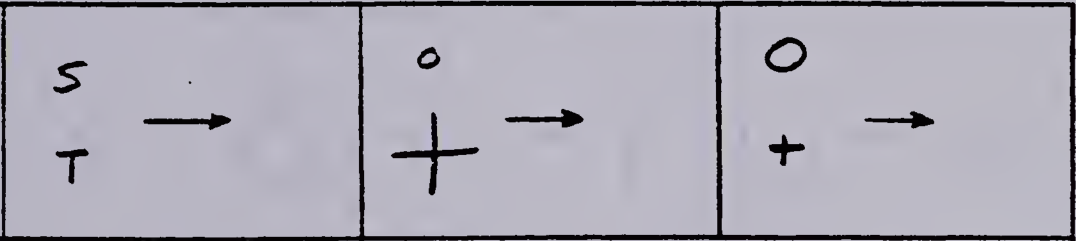
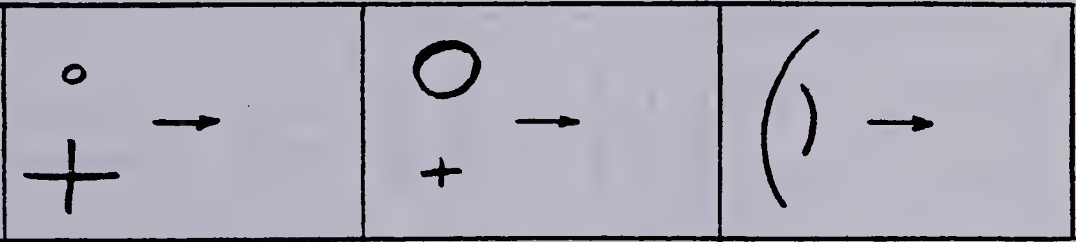
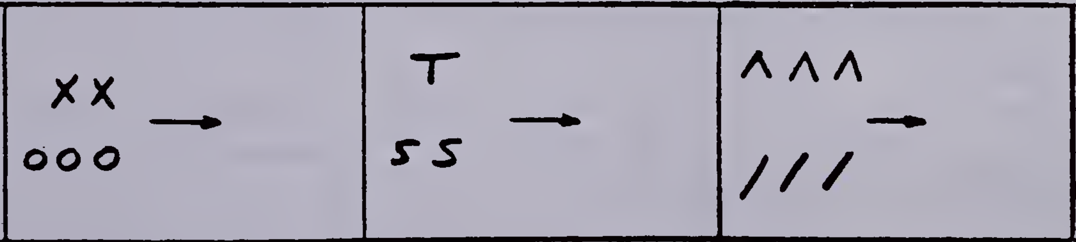


Do Operation E on these.



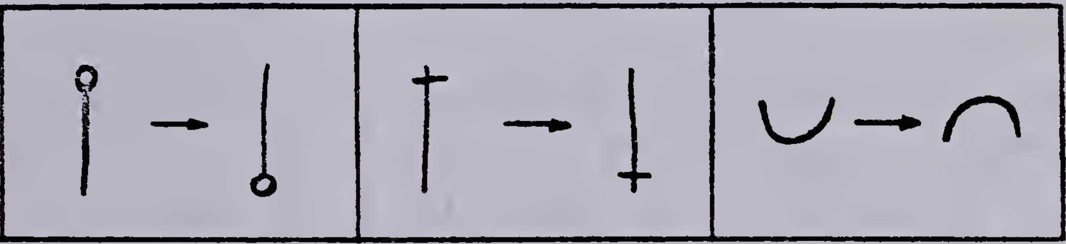
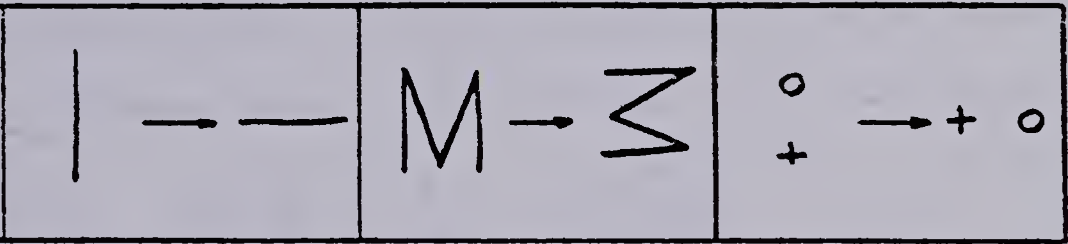
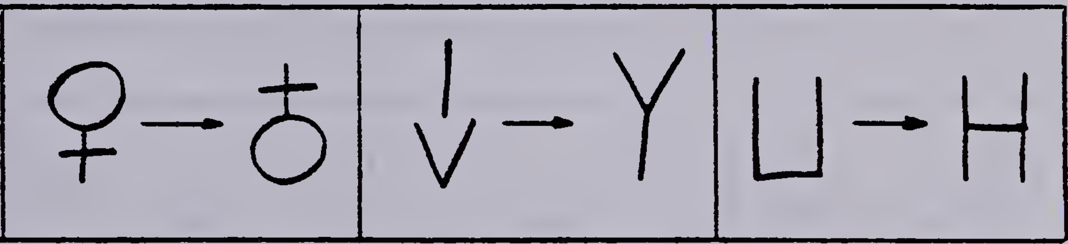
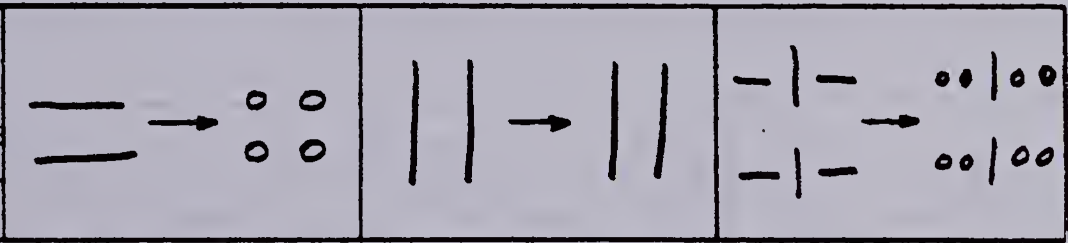
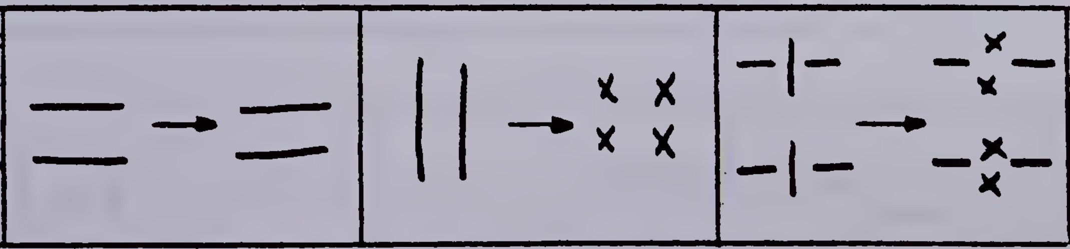
SK6: PART I

(CONTINUED)

Do Operation F on these.	
Do Operation G on these.	
Do Operation H on these.	
Do Operation I on these.	
Do Operation J on these.	

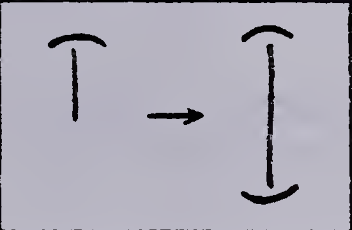
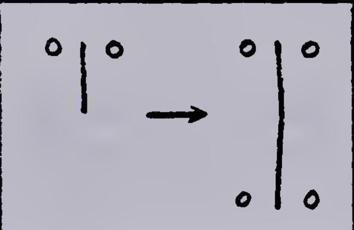
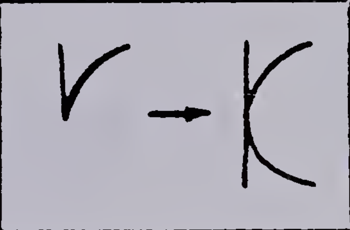
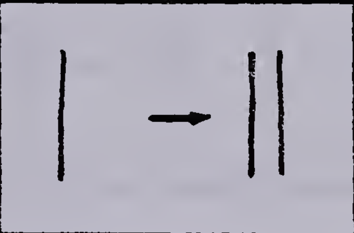
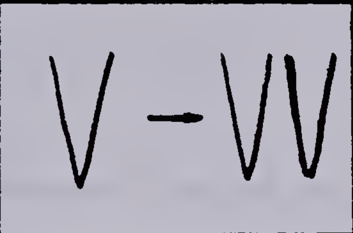
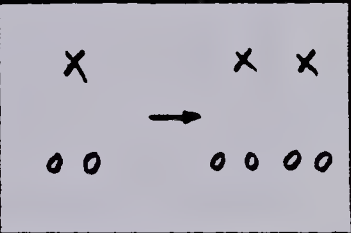
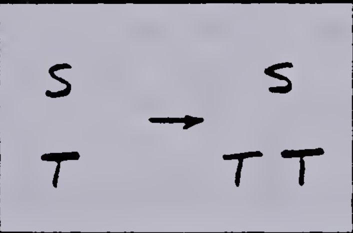
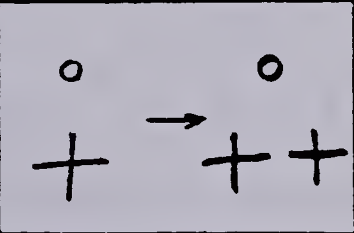
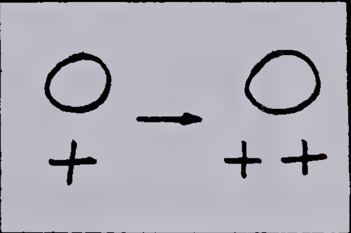
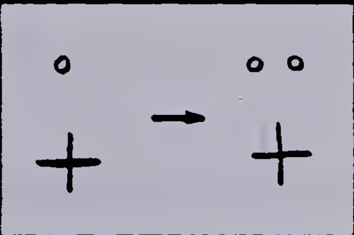
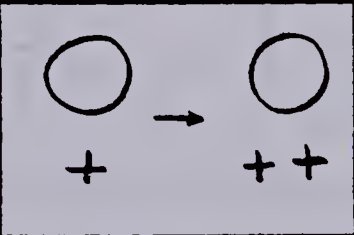
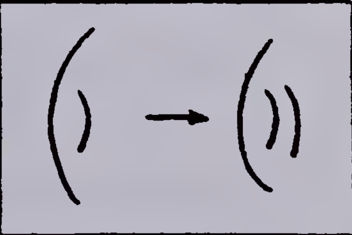
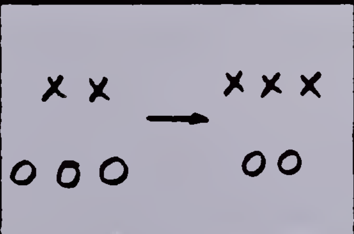
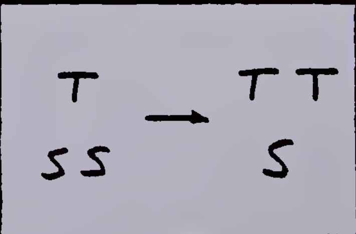
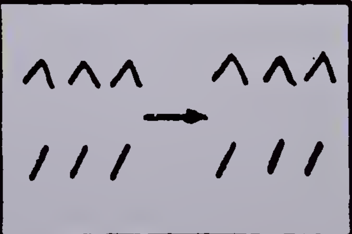
ANSWER SHEET FOR SK6, PART I

Here are the answers to the problems you did. Go through these carefully and put a tick in the right hand margin if you think that you got the whole line right. If you are not sure, ask for an explanation.

Operation A is: turn the other way up.	
Operation B is: rotate a quarter turn clockwise.	
Operation C is: interchange upper and lower parts.	
Operation D is: replace each horizontal line by two circles.	
Operation E is: replace each vertical line by two crosses.	

ANSWER SHEET FOR SK6, PART I

(CONTINUED)

Operation F is: add a symmetrical lower half.			
Operation G is: double everything.			
Operation H is: double the lower part.			
Operation I is: double the smaller part.			
Operation J is: interchange the numbers.			

NAME .... SCHOOL ....
Last First Middle

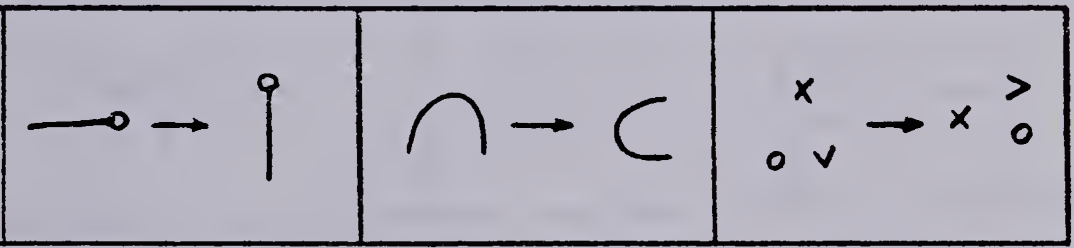
AGE .... GRADE .... BOY GIRL DATE ....
Years (Circle One) Day Month Yr.

SK6: PART II

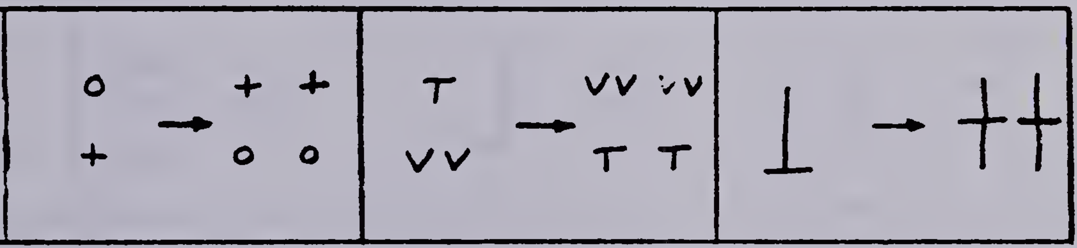
In PART II the problem is to combine the operations on the DEMONSTRATION SHEET, or to do them in reverse, or both. When combining operations, they are to be done in the order given (i.e., "Combine C and G" means "Do Operation C first and then do Operation G.")

Look at the examples given below and then carry out the operations indicated on the following three pages.

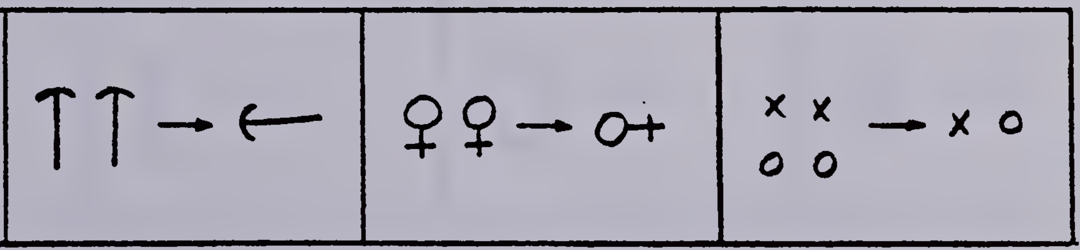
EXAMPLE:
Reverse B



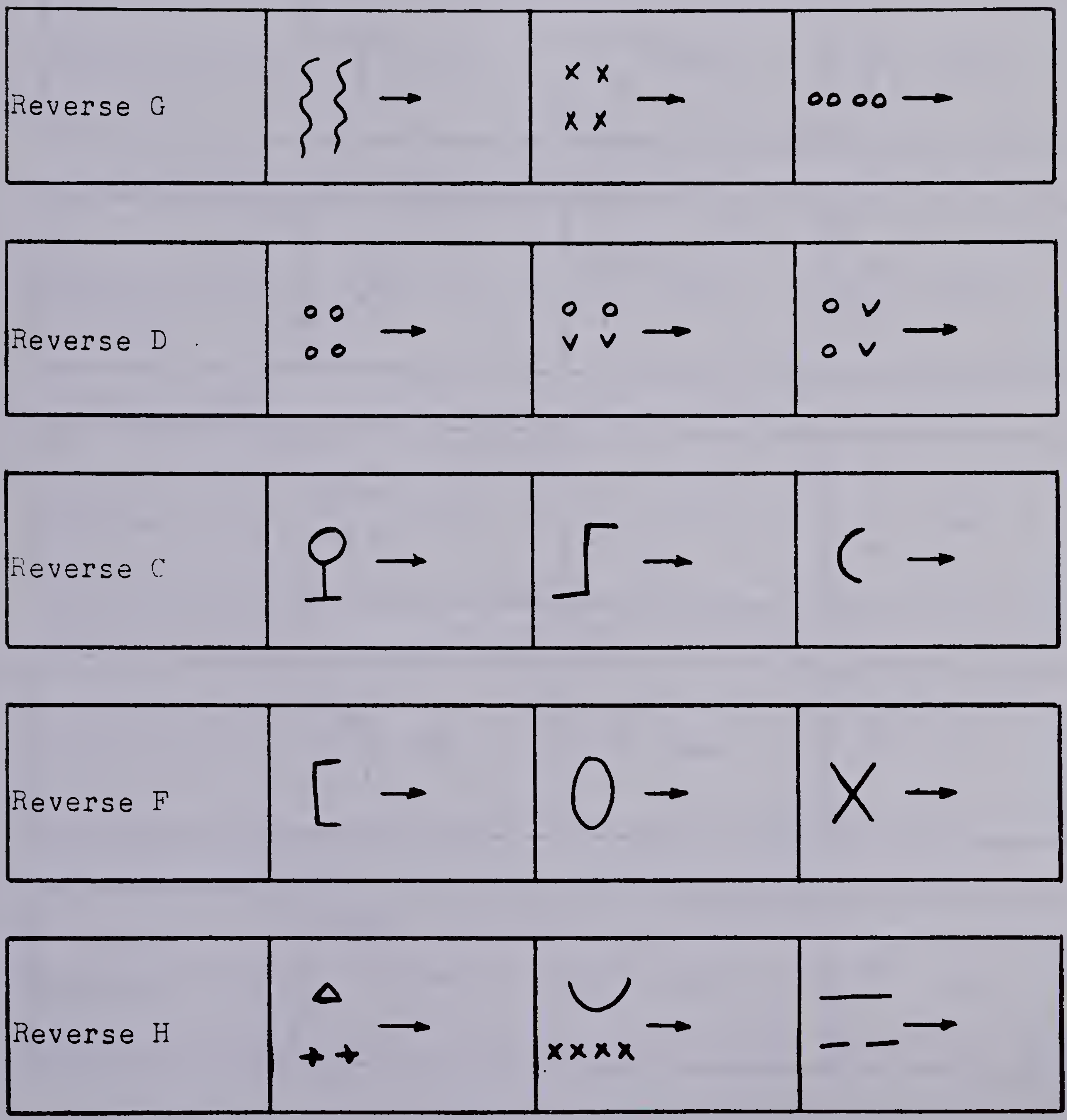
EXAMPLE:
Combine C & G



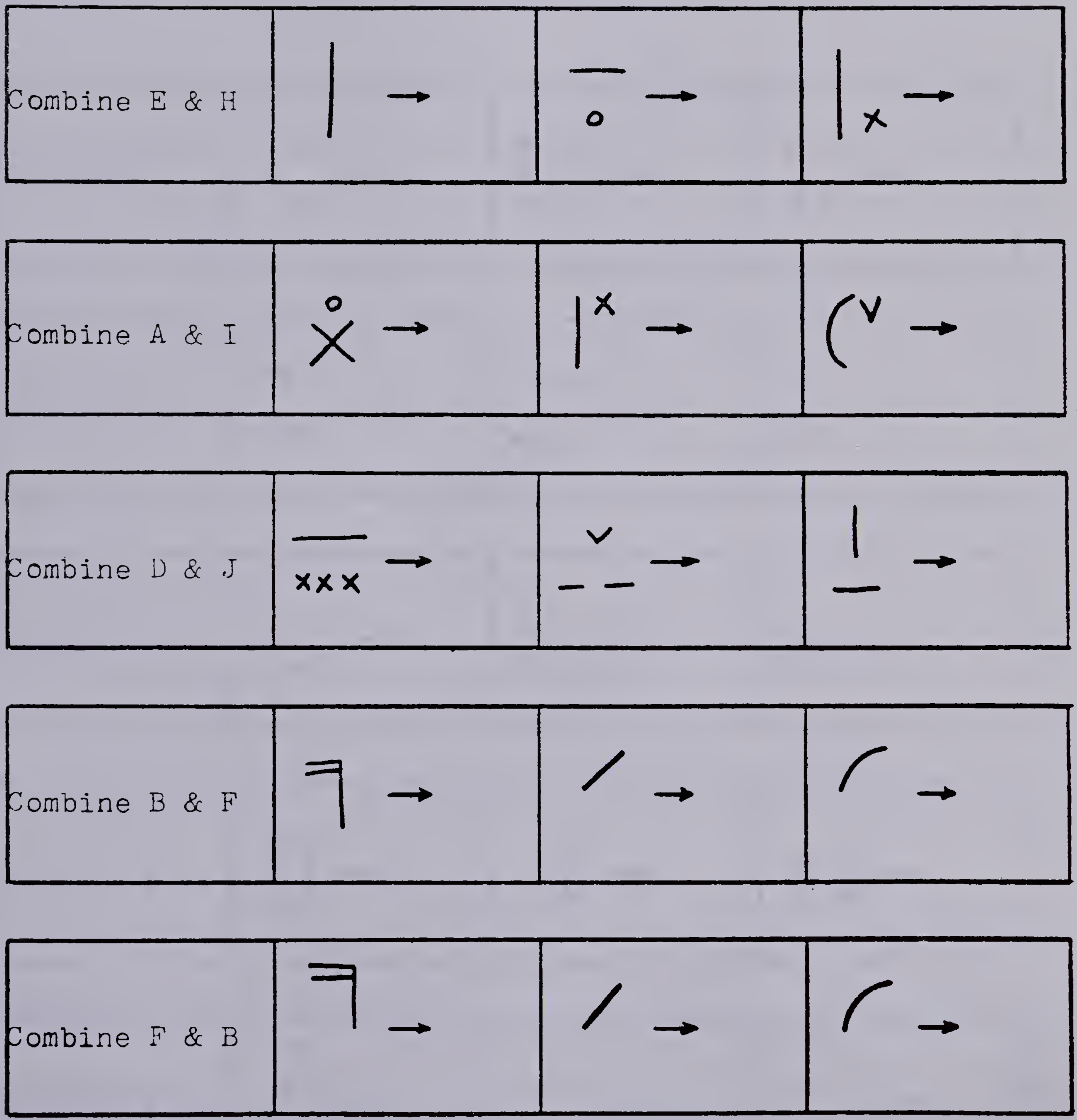
EXAMPLE:
Reverse and
Combine G & B



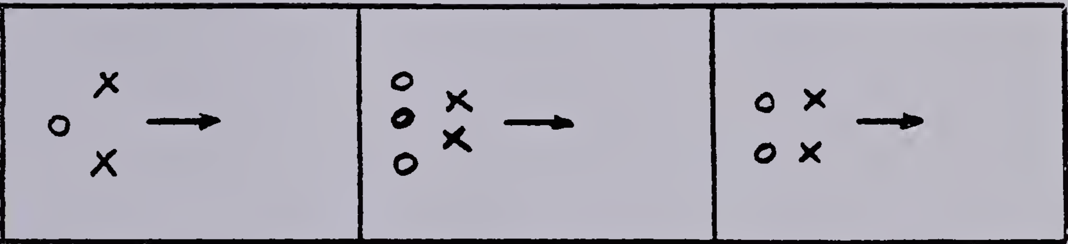
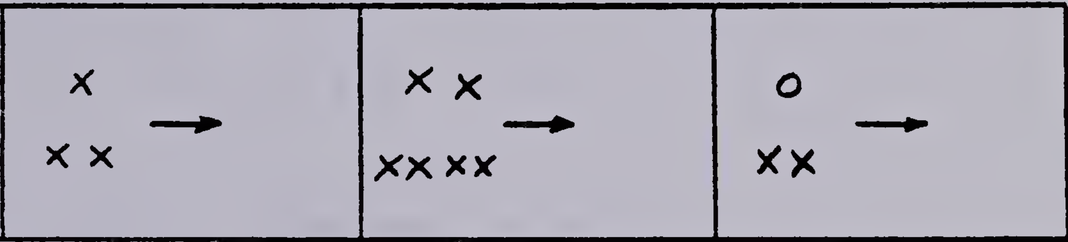
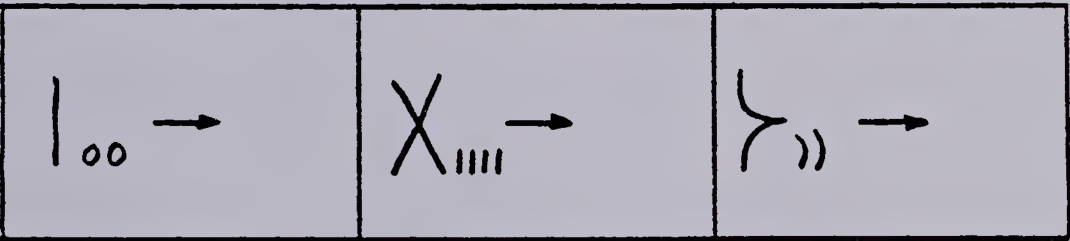
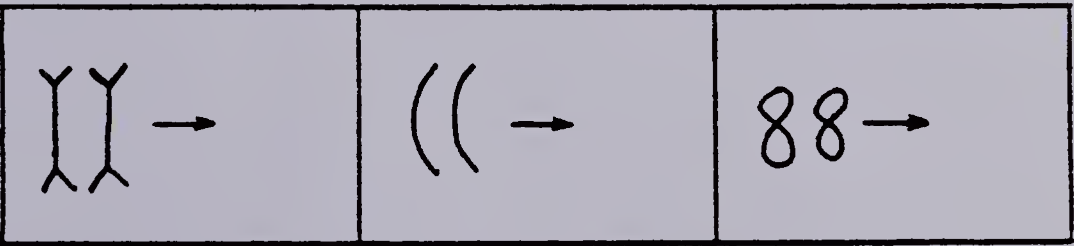
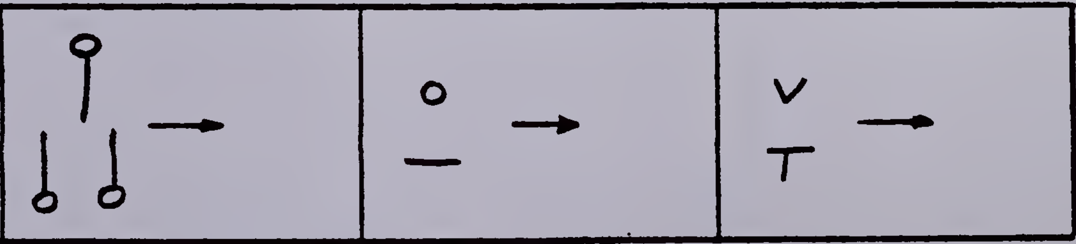
SK6: PART II



SK6: PART II



SK6: PART II

Reverse and Combine B & J	
Reverse and Combine H & E	
Reverse and Combine A & I	
Reverse and Combine F & G	
Reverse and Combine A & C	

A P P E N D I X C

LEARNING ENVIRONMENT INVENTORY

LEARNING ENVIRONMENT INVENTORY

Directions

The purpose of the questions on this booklet is to find out what your class is like. This is not a "test". You are asked to give your honest, frank opinions about the class which you are now attending.

Record your answers to each of the questions on the IBM card provided. Please make no marks on the booklet itself. Answer every question.

In answering each question go through the following steps:

1. Read the statement carefully.

2. Think about how well the statement describes your class (the one you are now in).

3. Find the number on the answer card that corresponds to the statement you are considering.

4. Blacken one space only on the answer card according to the following instructions:

   If you strongly disagree with the statement, blacken space 1.
   If you disagree with the statement, blacken space 2.
   If you agree with the statement, blacken space 3.
   If you strongly agree with the statement, blacken space 4.

5. You will have approximately 40 minutes to complete the 105 questions in the booklet. Be sure that the number on the answer card corresponds to the number of the statement being answered in the booklet.

		Strongly Disagree	Disagree	Agree	Strongly Agree
1.	Members of the class do favours for one another.	1	2	3	4
2.	The books and equipment students need or want are easily available to them in the classroom.	1	2	3	4
3.	There are long periods during which the class does nothing.	1	2	3	4
4.	The class has students with many different interests.	1	2	3	4
5.	Certain students work only with their close friends.	1	2	3	4
6.	The students enjoy their class work.	1	2	3	4
7.	Students who break the rules are penalized.	1	2	3	4
8.	There is constant bickering among class members.	1	2	3	4
9.	The better students' questions are more sympathetically answered than those of the average students.	1	2	3	4
10.	The class knows exactly what it has to get done.	1	2	3	4
11.	Interests vary greatly within the group.	1	2	3	4
12.	A good collection of books and magazines is available in the classroom for students to use.	1	2	3	4
13.	The work of the class is difficult.	1	2	3	4
14.	Every member of the class enjoys the same privileges.	1	2	3	4
15.	Most students want their work to be better than their friends' work.	1	2	3	4

		Strongly Disagree	Disagree	Agree	Strongly Agree
16.	The class has rules to guide its activities.	1	2	3	4
17.	Personal dissatisfaction with the class is too small to be a problem.	1	2	3	4
18.	A student has the chance to get to know all other students in the class.	1	2	3	4
19.	The work of the class is frequently interrupted when some students have nothing to do.	1	2	3	4
20.	Students cooperate equally with all class members.	1	2	3	4
21.	Many students are dissatisfied with much that the class does.	1	2	3	4
22.	The better students are granted special privileges.	1	2	3	4
23.	The objectives of the class are not clearly recognized.	1	2	3	4
24.	Only the good students are given special projects.	1	2	3	4
25.	Class decisions tend to be made by all the students.	1	2	3	4
26.	The students would be proud to show the classroom to a visitor.	1	2	3	4
27.	The pace of the class is rushed.	1	2	3	4
28.	Some students refuse to mix with the rest of the class.	1	2	3	4
29.	Decisions affecting the class tend to be made democratically.	1	2	3	4
30.	Certain students have no respect for other students.	1	2	3	4

	Strongly Disagree	Disagree	Agree	Strongly Agree
31. Some groups of students work together regardless of what the rest of the class is doing.	1	2	3	4
32. Members of the class are personal friends.	1	2	3	4
33. The class is well organized.	1	2	3	4
34. Some students are interested in completely different things than other students.	1	2	3	4
35. Certain students have more influence on the class than others.	1	2	3	4
36. The room is bright and comfortable.	1	2	3	4
37. Class members tend to pursue different kinds of problems.	1	2	3	4
38. There is considerable dissatisfaction with the work of the class.	1	2	3	4
39. Failure of the class would mean little to individual members.	1	2	3	4
40. The class is disorganized.	1	2	3	4
41. Students compete to see who can do the best work.	1	2	3	4
42. Certain students impose their wishes on the whole class.	1	2	3	4
43. A few of the class members always try to do better than the others.	1	2	3	4
44. There are tensions among certain groups of students that tend to interfere with class activities.	1	2	3	4
45. The class is well-organized and efficient.	1	2	3	4

		Strongly Disagree	Disagree	Agree	Strongly Agree
46.	Students are constantly challenged.	1	2	3	4
47.	Students feel left out unless they compete with their classmates.	1	2	3	4
48.	Students are asked to follow strict rules.	1	2	3	4
49.	The class is controlled by the actions of a few members who are favoured.	1	2	3	4
50.	Students don't care about the future of class as a group.	1	2	3	4
51.	Each member of the class has as much influence as any other member.	1	2	3	4
52.	The members look forward to coming to class meetings.	1	2	3	4
53.	The subject studied requires no particular aptitude on the part of the students.	1	2	3	4
54.	Members of the class don't care what the class does.	1	2	3	4
55.	There are displays around the room.	1	2	3	4
56.	All students know each other very well.	1	2	3	4
57.	The classroom is too crowded.	1	2	3	4
58.	Students are not in close enough contact to develop likes or dislikes for one another.	1	2	3	4
59.	The class is rather informal and few rules are imposed.	1	2	3	4
60.	Students have little idea of what the class is attempting to accomplish.	1	2	3	4

		Strongly Disagree	Disagree	Agree	Strongly Agree
61.	There is a recognized right and wrong way of going about class activities.	1	2	3	4
62.	What the class does is determined by all the students.	1	2	3	4
63.	After the class, the students have a sense of satisfaction.	1	2	3	4
64.	Most students cooperate rather than compete with one another.	1	2	3	4
65.	The objectives of the class are specific.	1	2	3	4
66.	Students in the class tend to find the work hard to do.	1	2	3	4
67.	Each student knows the goals of the course.	1	2	3	4
68.	All classroom procedures are well-established.	1	2	3	4
69.	Certain students in the class are responsible for petty quarrels.	1	2	3	4
70.	Many class members are confused by what goes on in class.	1	2	3	4
71.	The class is made up of individuals who do not know each other well.	1	2	3	4
72.	The class divides its efforts among several purposes.	1	2	3	4
73.	The class has plenty of time to cover the prescribed amount of work.	1	2	3	4
74.	Students who have past histories of being discipline problems are discriminated against.	1	2	3	4
75.	Students do not have to hurry to finish their work.	1	2	3	4

		Strongly Disagree	Disagree	Agree	Strongly Agree
76.	Certain groups of friends tend to sit together.	1	2	3	4
77.	There is much competition in the class.	1	2	3	4
78.	The subject presentation is too elementary for many students.	1	2	3	4
79.	Students are well-satisfied with the work of the class.	1	2	3	4
80.	A few members of the class have much greater influence than the other members.	1	2	3	4
81.	There is a set of rules for the students to follow.	1	2	3	4
82.	Certain students don't like other students.	1	2	3	4
83.	The class realizes exactly how much work it has to do.	1	2	3	4
84.	Students share a common concern for the success of the class.	1	2	3	4
85.	There is little time for day-dreaming.	1	2	3	4
86.	The class is working toward many different goals.	1	2	3	4
87.	The class members feel rushed to finish their work.	1	2	3	4
88.	Certain students are considered uncooperative.	1	2	3	4
89.	Most students sincerely want the class to be a success.	1	2	3	4
90.	There is enough room for both individual and group work.	1	2	3	4

		Strongly Disagree	Disagree	Agree	Strongly Agree
91.	Each student knows the other members of the class by their first names.	1	2	3	4
92.	Failure of the class would mean nothing to most members.	1	2	3	4
93.	The class has difficulty keeping up with its assigned work.	1	2	3	4
94.	There is a great deal of confusion during class meetings.	1	2	3	4
95.	Different students vary a great deal regarding which aspect of the class they are interested in.	1	2	3	4
96.	Each student in the class has a clear idea of the class goals.	1	2	3	4
97.	Most students cooperate equally with other class members.	1	2	3	4
98.	Certain students are favoured more than the rest.	1	2	3	4
99.	Students have a great concern for the progress of the class.	1	2	3	4
100.	Certain students stick together in small groups.	1	2	3	4
101.	Most students consider the subject matter easy.	1	2	3	4
102.	The course material is covered quickly.	1	2	3	4
103.	There is an undercurrent of feeling among students that tends to pull the class apart.	1	2	3	4
104.	Many students in the school would have difficulty doing the advanced work of the class.	1	2	3	4
105.	Students seldom compete with one another.	1	2	3	4

APPENDIX D

MATHEMATICS ACHIEVEMENT TEST

MATH EIGHT
MEASUREMENT

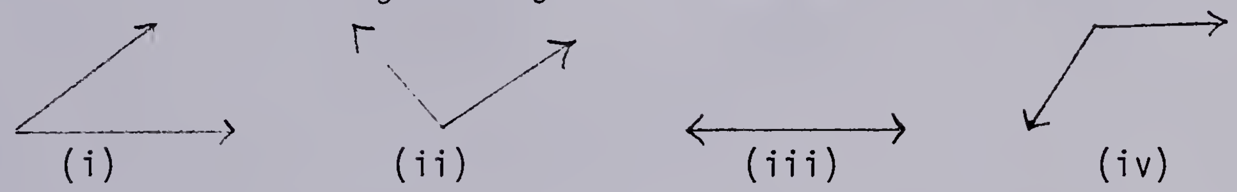
NAME ____________________ SCORE C __________

NUMBER ________________ P __________

TEACHER'S NAME __________ T __________

ANSWER ALL QUESTIONS ON THIS PAPER.

1. Which of the following are angles?



a. all of the above (c) (i), (ii) and (iii)

b. (i) and (ii) (d) none of the above

2. You need a piece of tape to patch a tear in your nylon tent. The tear is 234 mm long. Which of the following lengths of tape would be most appropriate for the task?

a. 2500 cm c. 25 cm

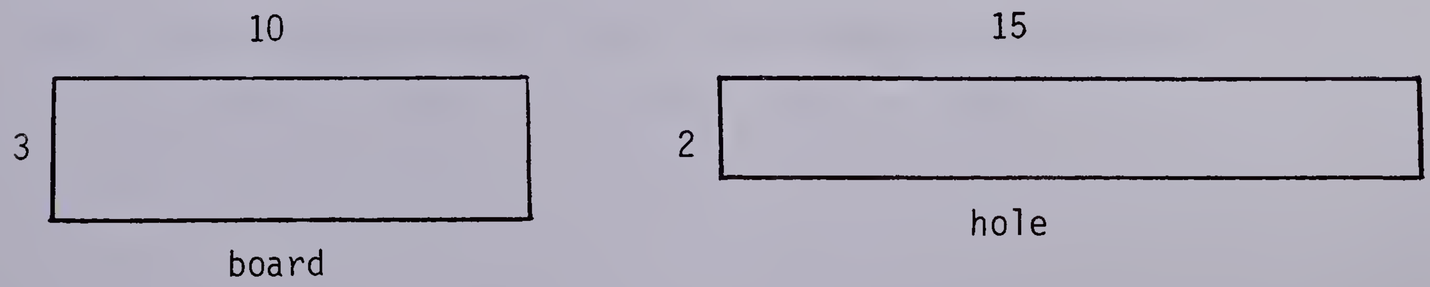
b. 250 cm d. 2.5 cm

3. Area is always measured in __________ units.

a. linear c. metric

b. square d. any of the above

4. Show how you can cut the board into <u>two equal</u> pieces to completely cover the hole.

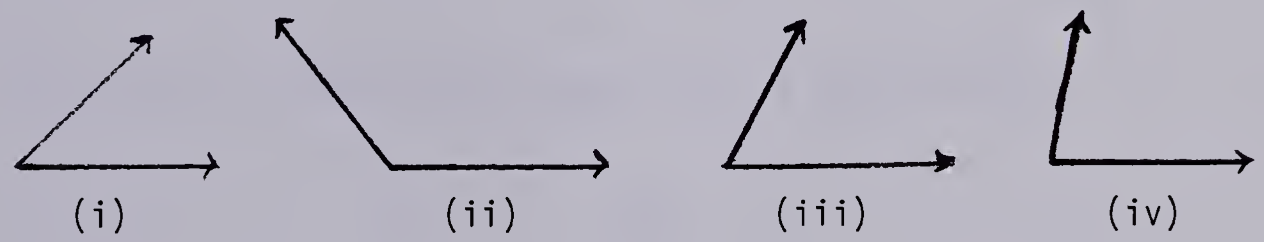


5. Which of the following units would not be appropriate for making body measurements?

a. metre c. centimetre

b. kilometre d. millimetre

6. Without using a protactor, the angle with a measure of 60° is:



a. (i) c. (iii)

b. (ii) d. (iv)

7. In the Metric System, to convert from a larger to the NEXT smaller <u>area</u> unit we must:

a. multiply by 10 c. multiply by 100

b. divide by 100 d. divide by 10

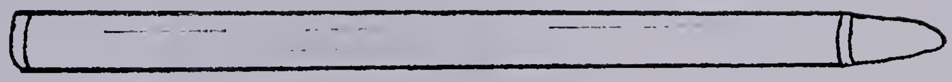
8. Bob ties boxes for a gift wrapping firm. It takes 1.5 metres of ribbon to tie each box. A roll of ribbon is 50 metres. How many boxes can he tie with one roll? How long is the piece remaining?

9. The list of metric units of area from largest to smallest is:

a. cm^2, dm^2, m^2, km^2 c. km^2, dm^2, m^2, cm^2

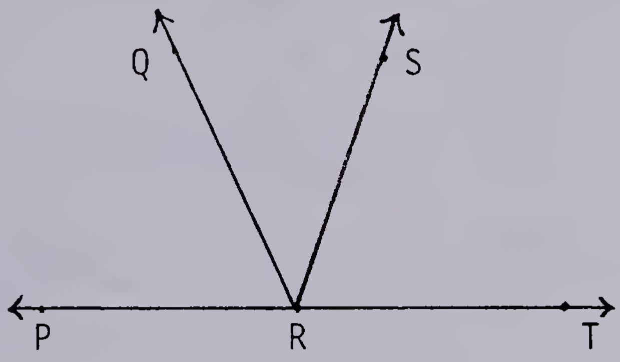
b. dm^2, cm^2, m^2, km^2 d. km^2, m^2, dm^2, cm^2

10. About how long is this crayon?



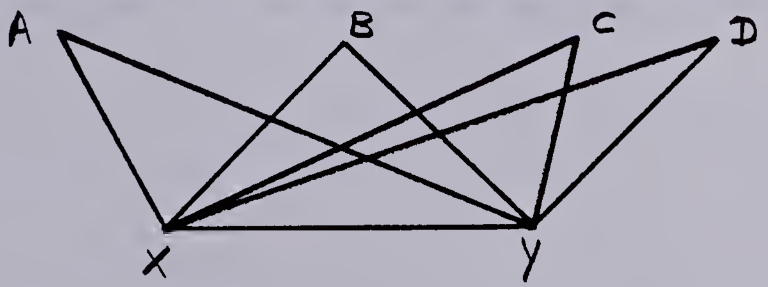
a. 1 cm
b. 10 cm
c. 1 m
d. 10 m

11. The measure of angle QRT, shown below is approximately:

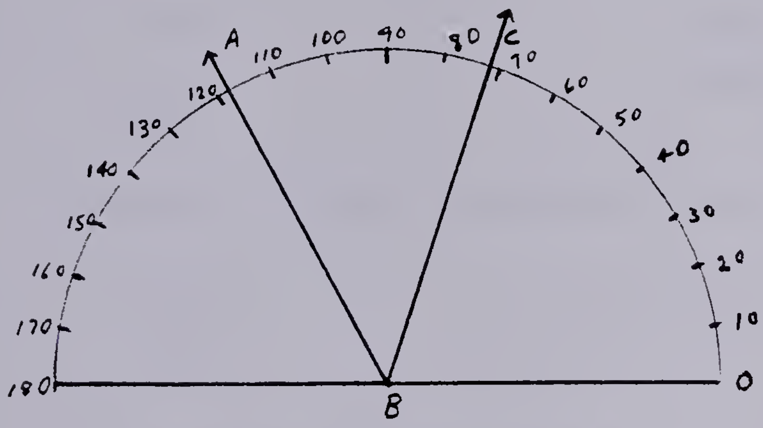


a. 150°
b. 30°
c. 120°
d. 60°

12. Which, if any, of the following triangles, AXY, BXY, CXY, DXY, have equal areas? Give some reason for your answer.



13. The measure in degrees of ∠ ABC shown below is approximately:



a. 72

b. 45

c. 118

d. 30

14. An area of 5 m^2 is not the same as:

a. 0.0005 cm^2

b. 0.000005 km^2

c. 50 000 cm^2

d. 500 dm^2

15. One metre is the same as:

a. 10 cm

b. 100 mm

c. 0.001 km

d. 0.01 cm

16. If the length of all the sides of a box is doubled, the area of the bottom of the box will be increased by what factor? Explain your answer.

17. One centimetre is not equivalent to:

    a. 10 mm
    b. $\frac{1}{100}$ m
    c. 0.00001 km
    d. 0.001 m

18. The number of metres in the sum 17 cm + 3 m + 28 000 mm is:

    a. 48.000
    b. 31.017
    c. 28 020
    d. 31.17

19. One (1) hectare is equivalent to:

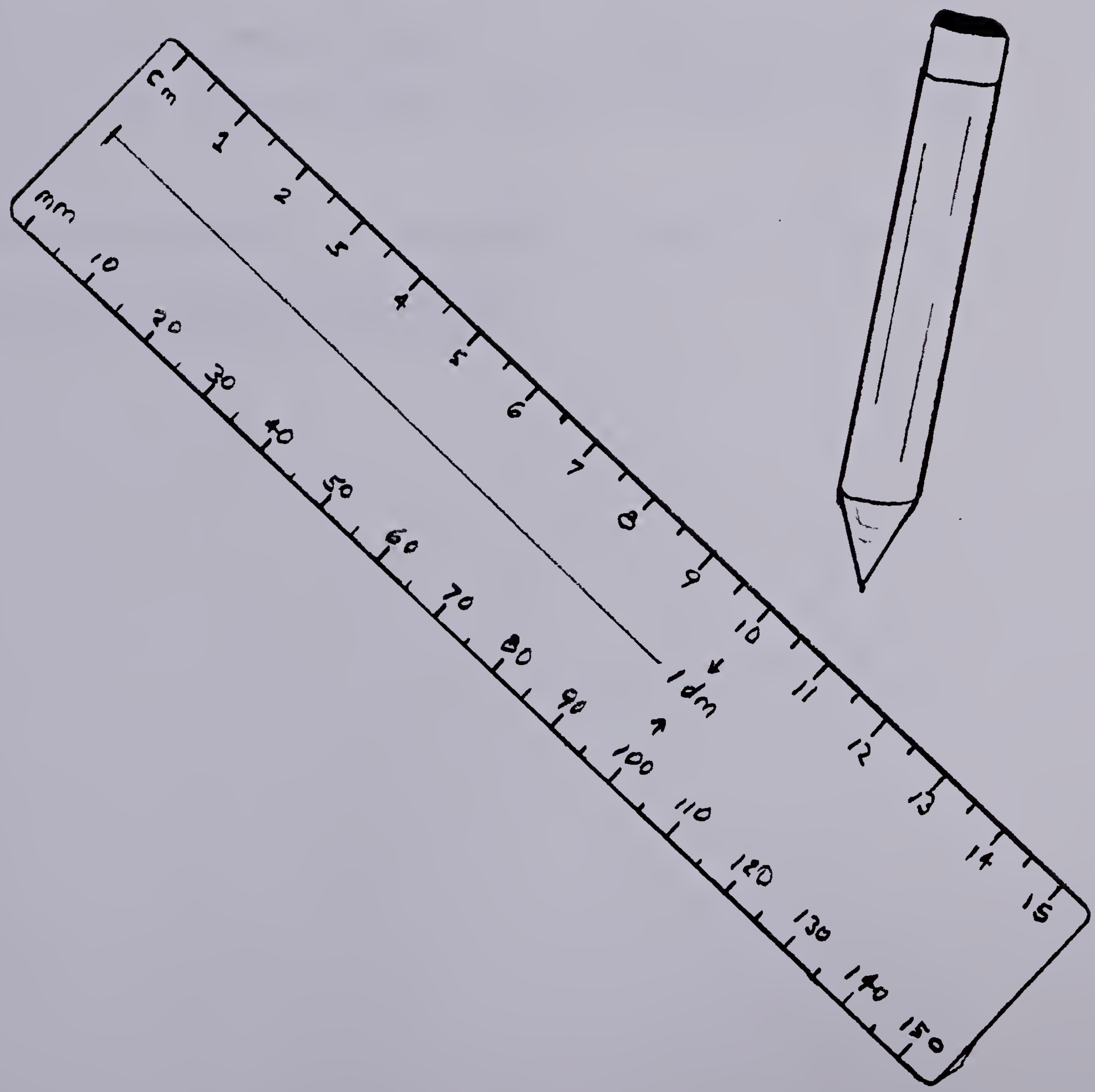
    a. 10 000 m^2
    b. 100 hm
    c. 10 km^2
    d. 100 m

20. A classroom which is 10 metres wide and 15 metres long is to be tiled. A tile is 9 dm^2 . (i) How many tiles would be needed to cover the floor? (ii) At a cost of 2¢ for each 100 cm^2 , how much would it cost to tile the classroom?

A P P E N D I X   E

MEASUREMENT INSTRUCTIONAL MATERIALS

LINEAR MEASURE



LINEAR MEASUREMENT UNIT

After completing this unit you should be able to:

1. Use the SI System of Measurement for lengths (km, hm, dam, m, dm, cm, mm).
2. Convert from one unit to another.
3. Add, subtract, multiply and divide the units.
4. Be able to estimate distances using the metric units.

If at any time you are unsure of the concepts developed in this unit, consult with your fellow students, available mathematics materials, or your teacher.

For extra practice, it is advisable to complete the exercises in your consortium student exercise book.

Linear Measure

Materials needed: (1) Measuring instrument with mm and cm markings

(2) Metre Stick

(3) Metric Measuring Tape

(4) Alberta Road Map

The unit on the ruler which has a width about the same as a toothpick or fingernail is a MILLIMETRE. It is normally written as mm.

Using this measure, how wide is your pencil? _____ mm.

How wide is your finger? _____ mm.

How long is your little finger? _____ mm.

How thick is your math book? _____ mm.

How long is your math book? _____ mm.

How long and wide is your desk? _____ mm _____ mm.

Each of these measurements are in millimetres. It is the smallest unit you will normally use for measuring length. How many millimetres (mm) long would your math book be? (Maybe too many!)

To measure the length of larger objects, it may be better to use a CENTIMETRE (cm). It is about the width of your little finger. This line segment is 1 cm long ├──┤ . Locate the centimetre markings on your ruler.

Using this measure, how wide is your little finger? _____ cm.

How wide is your thumb? _____ cm.

How long is your math book? _____ cm.

How long and wide is your desk? Length _____ cm. Width _____ cm.

Some of these measures you have already made using millimetres. Compare these measures using both millimetres and centimetres.

How many millimetres does it take to make a centimetre? That is, 1 cm = _____ mm.

Exercises: 1 centimetre = _____ millimetres

(a) 3 cm = _____ mm (b) 5 cm = _____ mm

(c) 7.5 cm = _____ mm (d) 10 cm = _____ mm

(e) ______ cm = 50 mm (f) ______ cm = 80 mm

(g) ______ cm = 85 mm (h) ______ cm = 97 mm

(i) ______ cm = 100 mm

Recall: It takes 10 mm to make 1 cm. <u>THEN</u> to <u>CONVERT</u> from cm to mm we multiply by _____. To <u>CONVERT</u> from mm to cm we divide by _____.

A further unit of length for small measures is a decimetre (dm). It is about as long as this segment.

1 decimetre

Use this measure to find the length and width of this sheet. Length _____ dm. Width _____ dm. How many decimetres long and wide is your desk? Length _____ dm. Width _____ dm.

Recall that your desk was _____ cm long and _____ cm wide. It is also _____ dm long and _____ dm wide.

How many centimetres long is a decimetre. 1 dm = _____ cm. Check using the decimetre segment. But, 1 cm = 10 mm.

How many millimetres long is a decimetre. 1 dm = _____ mm.

So 1 dm = _____ cm = _____ mm.

Exercises: 1 decimetre = 10 centimetres = 100 millimetres

(a) 5 dm = ______ cm = ______ mm.

(b) 7.5 dm = ______ cm = ______ mm.

(c) 9.55 dm = ______ cm = ______ mm.

(d) 10 dm = ______ cm = ______ mm.

(e) _____ dm = 70 cm = ______ mm.

(f) _____ dm = 85 cm = ______ mm.

(g) _____ dm = ______ cm = 900 mm.

(h) _____ dm = ______ cm = 950 mm.

(i) _____ dm = ______ cm = 1 000 mm.

Recall: It takes 100 mm or 10 cm to make 1 dm.

To convert from decimetres to centimetres we multiply by ______.

To convert from decimetres to millimetres we multiply by ______.

To convert from centimetres to decimetres we divide by ______.

To convert from millimetres to decimetres we divide by _____.

The Metric Units for measuring lengths of small objects are:

1. millimetre 2. centimetre 3. decimetre

Estimate the length of the following objects. Check using your ruler.

	Estimate dm	Estimate cm	Estimate mm	Actual dm	Actual cm	Actual mm
(a) Longest finger	____	____	____	____	____	____
(b) Left arm	____	____	____	____	____	____
(c) Your height	____	____	____	____	____	____
(d) The height of your desk	____	____	____	____	____	____
(e) Your teacher's height	____	____	____	____	____	____
(f) Any other object	____	____	____	____	____	____

Linear Measure II

Recall earlier that measurement of length in the Metric System could be performed using millimetres, centimetres and decimetres.

ALSO, 1 centimetre = 10 millimetres

1 decimetre = 10 centimetres = 100 millimetres

These units were small and would not be very efficient for longer distances (eg. length of the classroom, measuring race distances, road distances or measuring your home). Other larger unit measures are more appropriate for these measures.

The METRE (m) is the basic unit of linear (length) measurement in the Metric System. It is about the same width as a classroom door. In fact, it is exactly the length of the metre stick available to you.

Use your metre stick to measure some objects. Try measuring:

The length and width of the classroom. Length _____ m. Width _____ m.

Your teacher's height. _____ m.

The distance to the next classroom, gym or length of the corridor outside your classroom. _____ m.

<u>Estimate</u>: How many metres long is your home? _____ m.

How many metres long is a Volkswagen Rabbit? _____ m .

Dodge Van? _____ m.

Examine your metre stick closely. It has other markings or units on it. What are they? ____.

How many decimetres will be on a metre stick? ______ dm. How many centimetres? ______ cm. Millimetres? ______ mm.

So, what did you find? Are all the measurement units related somehow?

1 metre = ______ dm = ______ cm = ______ mm.

Exercises:

(a) 5 m = ______ dm = ______ cm = ______ mm.

(b) 7.5 m = ______ dm = ______ cm = ______ mm.

(c) 10 m = ______ dm = ______ cm = ______ mm.

(d) ______ m = 30 dm = ______ cm = ______ mm.

(e) ______ m = ______ dm = 250 cm = ______ mm.

(f) ______ m = ______ dm = ______ cm = 7 000 mm.

Recall: To convert from metres to decimetres we multiply by ______.

To convert from metres to centimetres we multiply by ______.

To convert from metres to millimetres we multiply by ______.

To convert from decimetres to metres we divide by ______.

To convert from centimetres to metres we divide by ______.

To convert from millimetres to metres we divide by _____.

Anything familiar here? How many times larger is a unit than the one directly below it? ______. To convert from a larger unit to a smaller one we multiply by _____ for each step down.

How many steps down from metre to decimetre? _____ we multiply by _____.

How many steps down from metre to centimetre? _____ we multiply by _____.

How many steps down from metre to millimetre? _____ we multiply by _____.

Quickies:	(a) 7 m = _____ dm	(d) 1.4 dm = _____ cm.
	(b) 62 m = _____ cm	(e) 7 dm = _____ mm.
	(c) 4.2 m = _____ mm	(f) 0.4 cm = _____ mm.

Can you determine a method to change from smaller to larger units?

Recall: To convert from decimetres to metres we divide by ______.

To convert from centimetres to metres we divide by ______.

To convert from millimetres to metres we divide by ______.

How many steps up from decimetre to metre? ______.

How many steps up from centimetre to metre? ______.

How many steps up from millimetre to metre? ______.

Can you complete this sentence?

To change from a smaller length unit to a larger length unit we _____________ by ________ for each step up to the larger unit.

QUICKIES: (a) 20 mm = ______ cm (d) 450 dm = _____ m

(b) 42 cm = ______ dm (e) 70 000 mm = _____ dm

(c) 650 cm = ______ m (f) 62 mm = _____ m

Larger metric units of length follow the same basic rules for conversion.

The DECAMETRE (dam) is a unit of length about as long as a classroom. It is 10 m long. That is, 1 dam = 10 metres. It is not a commonly used measure but can be used if necessary. It is one (1) step larger than a metre.

So for conversion:

From decametres to metres we multiply by _____.

From metres to decametres we divide by _____.

Exercises:

(a) 17 dam = _____ m (c) 30 m = _____ dam

(b) 3.5 dam = _____ m (d) 75 m = _____ dam

(e) 7 dam = _____ cm

Other metric units of length larger than the metre are the HECTOMETRE (hm) and the KILOMETRE (km).

The HECTOMETRE is equivalent to 10 decametres or ____ metres. It is important for use in the measurement of land size. A football field is about one (1) hectometre long.

Measure a 1 hectometre length on the playing field outside your school. Ask your gym teacher to mark off a distance of 1 hectometre in the gym.

Do you know other things which measure about 1 hectometre?

The KILOMETRE (km) is a very common unit for measuring larger lengths such as road distances. It is a distance of 10 hectometres or 100 decametres or 1 000 metres. A distance across about 6 city blocks would be 1 km long. Can you imagine 1 000 metre sticks all in a line. That's one (1) kilometre!

Use an Alberta Road Map to complete these:

From Edmonton to Calgary is _________ km.

From Edmonton to Grand Prairie is _________ km.

From Edmonton to Jasper is _________ km.

From Edmonton to Wetaskiwin is _________ km.

From Jasper to Wetaskiwin is _________ km.

How far is it from Edmonton to Vancouver, B.C.? __________.

How far is it from Vancouver, B.C. to St. John's, Nfld? _________.

How long is the Trans Canada Highway? _________.

Recall: 1 km = 10 hm = 100 dam = 1 000 m

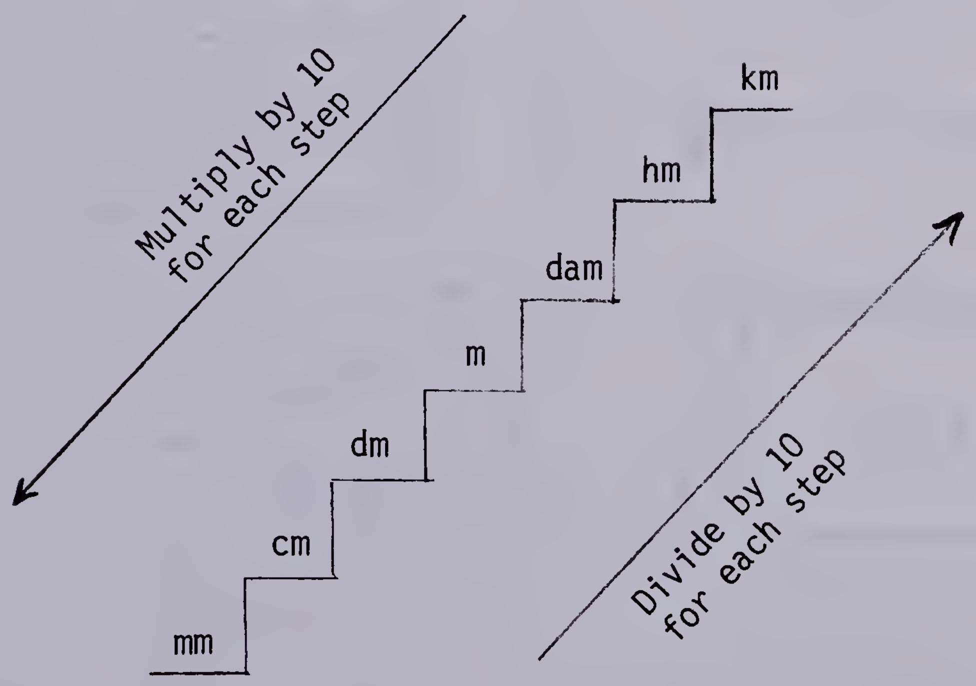
1 000 m = _______ dm = _______ cm = _______ mm.

ALSO, to convert from a larger unit to the next smaller unit we multiply by ______. How many steps down is this? _____.

How many steps down from		To convert multiply by
(a) kilometre to hectometre	_____	______
(b) kilometre to metre	_____	______
(c) hectometre to metre	_____	______ .

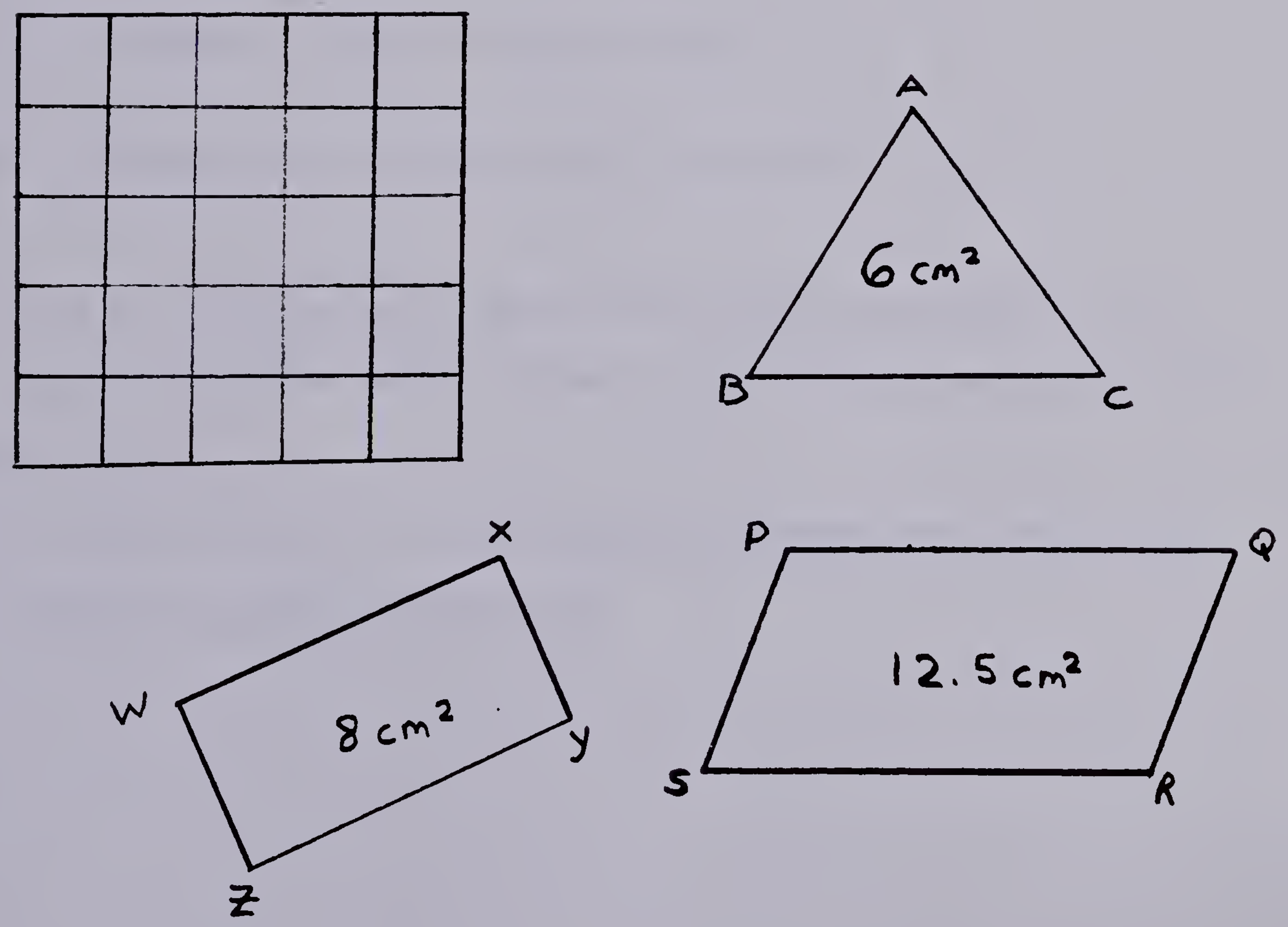
How many steps down		To convert multilpy by
(d) metre to centimetre	_____	_______
(e) metre to millimetre	_____	_______
(f) centimetre to millimetre	_____	_______

How many steps UP from	To convert divide by
(a) hectometre to kilometre	_______
(b) metre to kilometre	_______
(c) metre to hectometre	_______
(d) centimetre to metre	_______
(e) millimetre to metre	_______
(f) millimetre to centimetre	_______



*Complete the exercises in the Student's Workbook on pages 12 & 13.

AREA MEASURE



AREA MEASUREMENT UNIT

After completing this unit you should be able to:

1. Define Area Measure.

2. Use the SI System of measurement for area.

    a. State the appropriate prefixes for the units.

    b. State the relationship between the units. (km^2, hm^2, or ha, dam^2, m^2, dm^2, cm^2, mm^2).

3. Convert from one unit to another. (km^2, ha, m^2, cm^2, mm^2).

4. Do exercises using the proper units.

5. Estimate areas using the metric area units.

If at any time you are unsure of the concepts developed in this unit, consult with your fellow students, available mathematics materials, or your teacher.

For extra practice, it is advisable to complete the exercises in your <u>consortium student exercise book</u>.

Area Measure

Materials Needed: (1) Ruler (cm & mm)

(2) Metre Stick

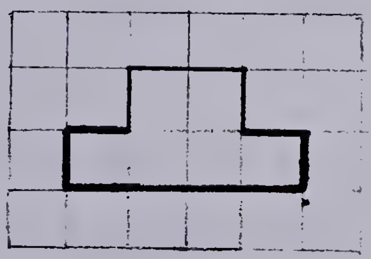
(3) Centimetre (cm) Grid Paper

(4) Newspaper

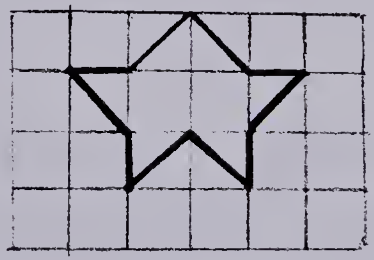
(5) Masking Tape

The area of any surface is thought of as the amount of space enclosed within the surface. We think of it as the number of unit squares within a region.

For example:



(a)

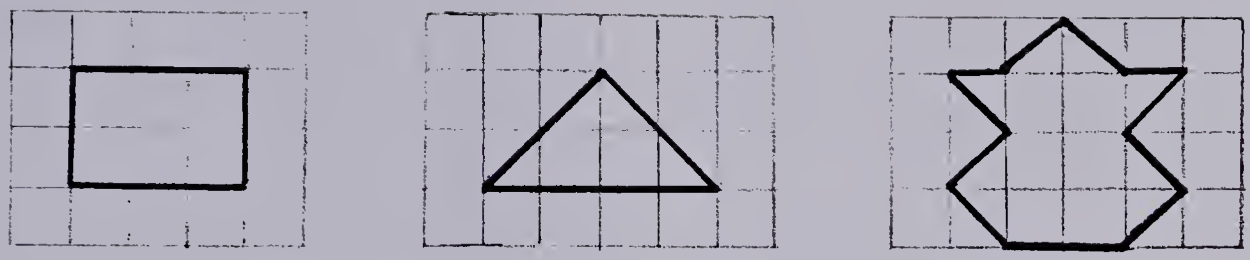


(b)

The area of figure (a) is 6 square units and the area of figure (b) is 5 square units. That is, 6 and 5 are the number of unit squares within (a) and (b) by counting.

What is the area of the following (ie. how many unit squares are within the region of each figure):

(a) (b) (c)



____ Square Units _____ Square Units _____ Square Units

How large is a square unit? Do you know what a square is? How about a unit? Look for a definition of these. Do units vary in size?

In the Metric System for LENGTH measures we use units of millimetre, centimetre, decimetre, metre, decametre, hectometre and kilometre. Recall that each unit of measure (mm, cm, ...) is 10 times larger than the next unit below it (1 cm = 10 mm).

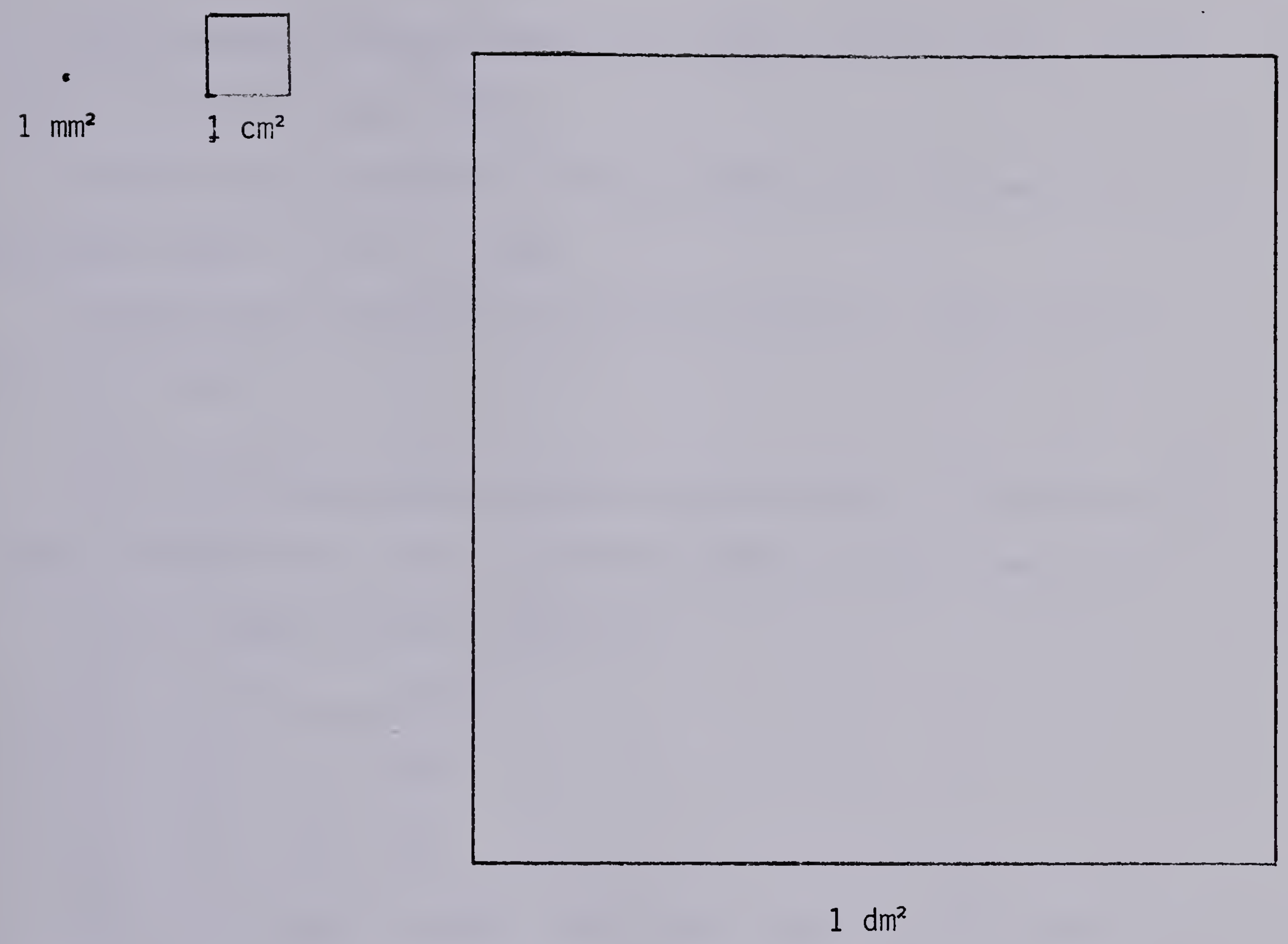
For measuring area, we can use these basic units. However, area is the number of unit squares within a region. So, we must use squares. That is, for area we must use square millimetres (mm^2), square centimetres (cm^2), square decimetres (dm^2) and so on.

Note: We write cm^2 to represent Square Centimetre.

We write mm^2 to represent Square Millimetre.

AND We write ___ to represent Square Metre.

Let's draw a square millimetre (mm^2), square centimetre (cm^2) and square decimetre (dm^2).



A square millimetre (mm^2) is about the size of a period on a typewriter key, the tip of a pen or tip of a pencil. It is a very small unit of area.

How many square millimetres could you place inside the square centimetre, the square decimetre? (Estimate, then check*)______ ______.

How many square centimetres can you place inside the square decimetre? ______ (check by drawing square centimetres).

(1) 1 dm^2 = ______ cm^2

(2) 1 dm^2 = ______ mm^2

(3) 1 cm^2 = ______ mm^2

*Use a text or ask your teacher

Using newspaper and your metre stick make a 1 metre square. It has an area of 1 square metre ($1m^2$).

Use your square decimetre to find how many square decimetres are in the square metre. $1\ m^2 =$ ____ dm^2.

How many square centimetres are enclosed within a square metre? $1m^2 =$ ____ cm^2.

The units of area measure already used are square millimetre (mm^2), square centimetre (cm^2), square decimetre (dm^2) and square metre (m^2).

From the above it can be seen that:

(1) $1\ m^2 =$ _____ dm^2

(2) $1\ dm^2 =$ _____ cm^2

(3) $1\ cm^2 =$ _____ mm^2

Each unit above is how many times larger than the unit below it ____? To convert from a larger area unit to a smaller area unit we multiply by _____ for each step down.

How many square centimetres is needed to cover the square decimetre _____?

How many square decimetres is needed to cover the square metre _____?

To convert from a smaller area unit to a larger area unit we divide by _____ for each step up.

<u>Exercises</u>: $1\ m^2 = 100\ dm^2 = 10\ 000\ cm^2 = 1\ 000\ 000\ mm^2$

$$100\ mm^2 = 1\ cm^2 = \frac{1}{100} \text{ or } .01\ dm^2 = \frac{1}{10\ 000} \text{ or } .0001\ m^2$$

(a) $5\ m^2$ = _____ dm^2

(b) $7\ dm^2$ = _____ cm^2

(c) $.02\ m^2$ = _____ cm^2

(d) _____ m^2 = $5\ 000\ cm^2$

(e) $2.5\ m^2$ = _____ cm^2

(f) $7\ dm^2$ = _____ mm^2

(g) _____ m^2 = $800\ dm^2$

(h) _____ m^2 = $50\ dm^2$

(i) $2.5\ m^2$ = _____ cm^2

(j) $2.5\ cm^2$ = _____ mm^2

(k) _____ dm^2 = $50\ cm^2$

<u>Measuring Area Using Square Centimetres, Square Decimetres and Square Metres</u>

Using your square centimetre grid, estimate then find the area of these objects by covering the object and counting the squares: Note the length and width:

	Estimate	Area	Length	Width
1. Chaulk brush	_____	_____ cm^2	_____ cm	_____ cm
2. Text book cover	_____	_____ cm^2	_____ cm	_____ cm
3. This sheet of paper	_____	_____ cm^2	_____ cm	_____ cm
4. Your desk	_____	_____ cm^2	_____ cm	_____ cm
5. Two (2) other objects in the room	_____	_____ cm^2	_____ cm	_____ cm

Using your square decimetre repeat the measurements with the objects above:

	Estimate	Area	Length	Width
1. Chaulk brush	_____	_____ dm^2	_____ dm	_____ dm
2. Text book cover	_____	_____ dm^2	_____ dm	_____ dm
3. This sheet of paper	_____	_____ dm^2	_____ dm	_____ dm
4. Your desk	_____	_____ dm^2	_____ dm	_____ dm
5. Two (2) other objects in the room	_____	_____ dm^2	_____ dm	_____ dm

Using your square metre estimate then find the areas of the following:

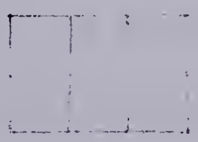
	Estimate	Area	Length	Width
1. Classroom	_____	_____ m^2	_____ m	_____ m
2. Classroom door	_____	_____ m^2	_____ m	_____ m
3. Chaulk board	_____	_____ m^2	_____ m	_____ m
4. Teacher's desk top	_____	_____ m^2	_____ m	_____ m
5. Wall (longest)	_____	_____ m^2	_____ m	_____ m
6. Window (if any)	_____	_____ m^2	_____ m	_____ m

The block (a) below has an area of 6 cm^2

The block (b) below has an area of 4 cm^2

a.

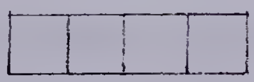
3 cm



2 cm

b.

4 cm



1 cm

	Length	Width	Area
a.	3 cm	2 cm	6 cm^2
b.	4 cm	1 cm	4 cm^2

Is there a relationship?

Check the measurements of area, length and width from before to determine if the relationship holds.

Is there an easier or more convenient way to determine the area of an objects without covering the complete object? How? ____________________.

Cut out triangles, parallelograms and rectangles with the same base and height. Can you determine an easy way to find the area of these figures without covering? (Use the sheet provided at the end of this unit).

Larger Units of Area

For finding the area of larger objects the units of square decametre (dam^2), square hectometre or hectare (ha) and square kilometre (km^2) are used.

The square decametre (dam^2) is a square with sides of size one (1) decametre or 10 metres. It would enclose a region of 100 square metres. A volleyball court or half a basketball court has an area of about one (1) square decametre. It is not a commonly used area measure; however, its relationship to the square metre ($1\ dam^2 = 100\ m^2$) is important.

The square hectometre is referred to as the hectare (ha). It is a square of sides 100 metres. It would enclose a region of 10 000 square metres. Two football fields placed side by side would have an area of about one (1) hectare. The hectare is used for land measurement and is thus a very important unit for large area measures.

Name some object which would have an area of about 1 ha, 5 ha, 10 ha.

The square kilometre (km^2) is also used for measuring very large areas. It is a square with sides of size one (1) kilometre or 10 hectometres or

1 000 metres. It would enclose a region of 1 000 000 square metres or 100 hectares. It would normally be used for establishing the area of a Province or Country.

What is the area of Alberta? __________ km^2

What is the area of Saskatchewan? __________ km^2

What is the area of British Columbia? __________ km^2

What is the area of Prince Edward Island? __________ km^2

What is the area of Canada? __________ km^2

Converting Between Area Units

Recall that 1 cm^2 = 100 mm^2 and

that 1 dm^2 = 100 cm^2 and

that 1 m^2 = 100 dm^2

From above, 1 dam^2 = 100 m^2 and

1 ha = 100 dam^2 and

1 km^2 = 100 ha (ha = hectare or 1 square hectometre)

For area measurement using the Metric System, each unit is 100 times as large as the one below it.

To convert from a larger area unit to a smaller area unit we multiply by ________ for each step down.

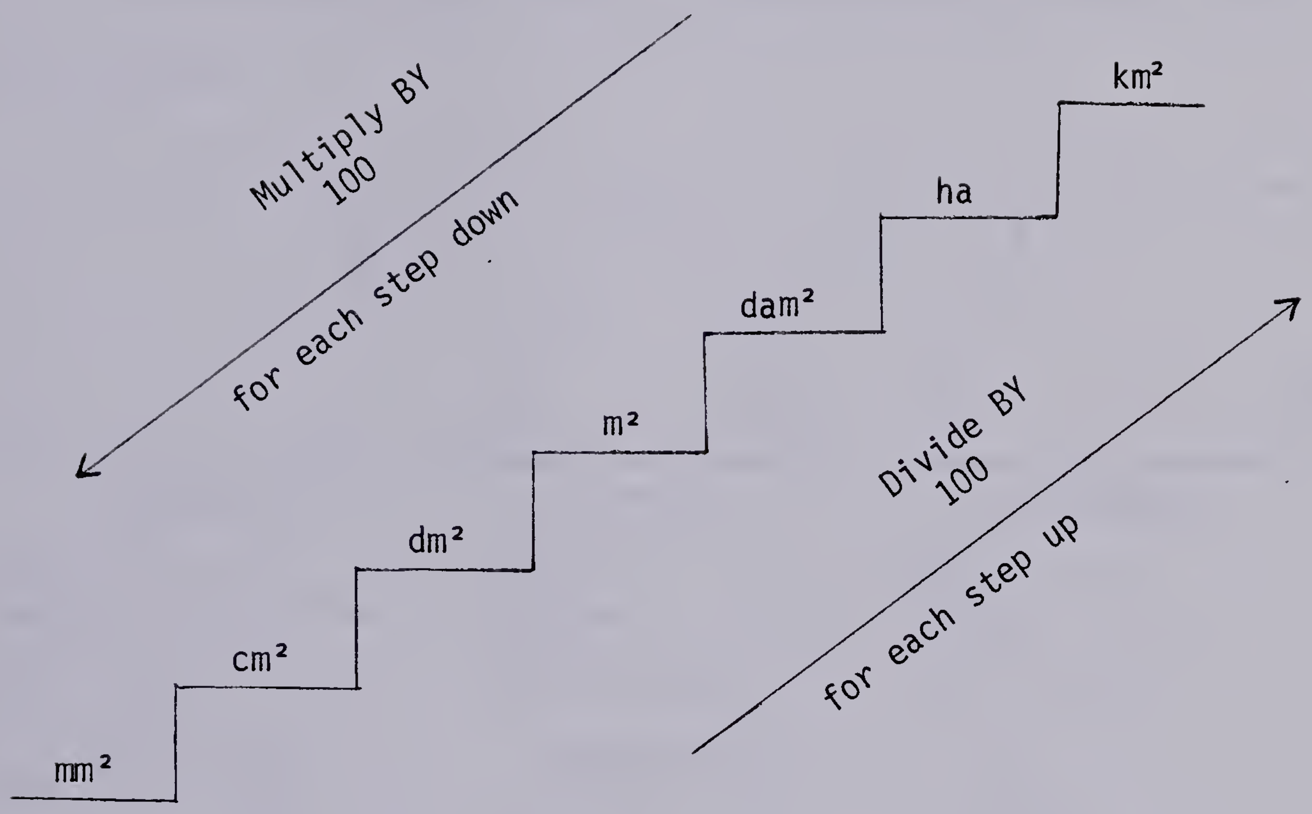
To convert from a smaller unit to a larger unit area we do the opposite, that is;

To convert from a smaller area unit to a larger area unit we divide by ________ for each step up.

How many steps down from		To convert muliply by
(a) km^2 to ha?	________	________
(b) km^2 to m^2?	________	________
(c) km^2 to cm^2?	________	________
(d) ha to m^2?	________	________
(e) m^2 to cm^2?	________	________
(f) m^2 to mm^2?	________	________

How many steps up from		To convert divide by
(a) m^2 to ha?	________	________
(b) ha to km^2?	________	________
(c) cm^2 to m^2?	________	________
(d) m^2 to km^2?	________	________
(e) mm^2 to m^2	________	________

Area Unit Conversion

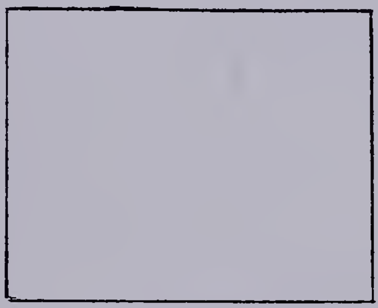


* Complete the exercises in the student's workbook on pages 14 to 20.

These rectangles, triangles and parallelograms have the same base and height. Find the area of each.

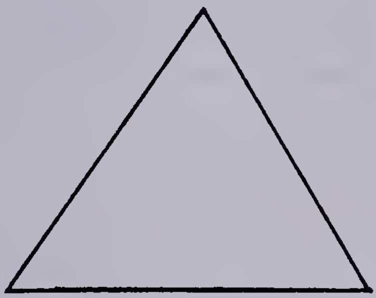
Can you determine an easy method to find the area of these figures without covering.

1.



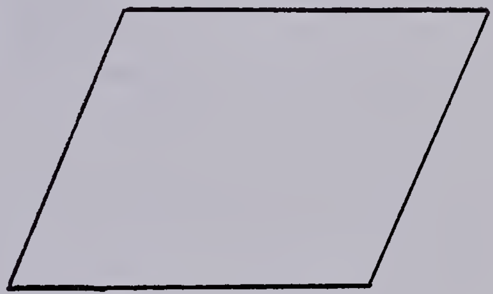
Rectangle

Base _______
Height _______
Area _______



Triangle

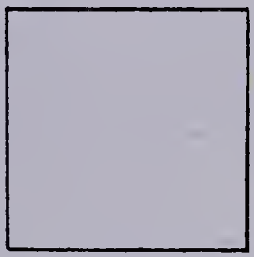
Base _______
Height _______
Area _______



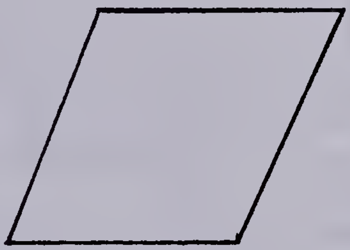
Parallelogram

Base _______
Height _______
Area _______

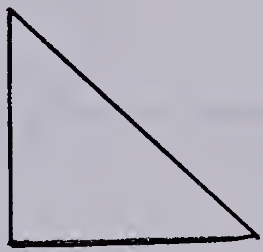
2.



Base _______
Height _______
Area _______



Base _______
Height _______
Area _______

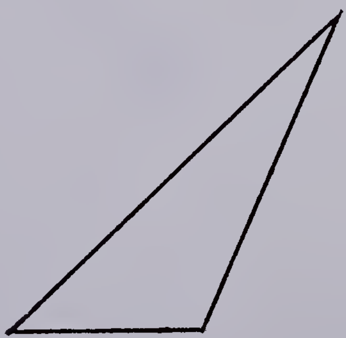


Base _______
Height _______
Area _______

3.

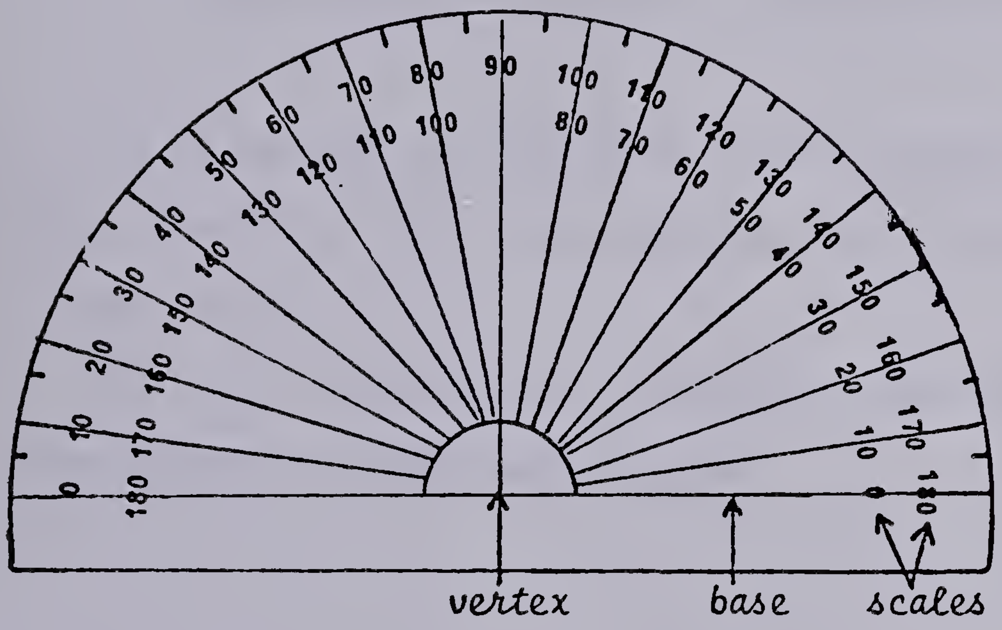
Base _______
Height _______
Area _______

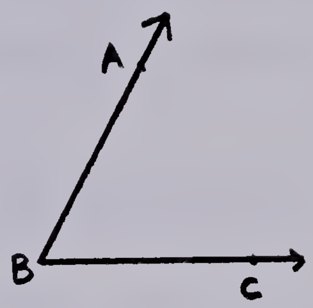
Base _______
Height _______
Area _______

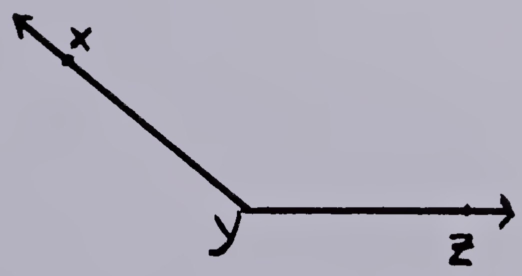


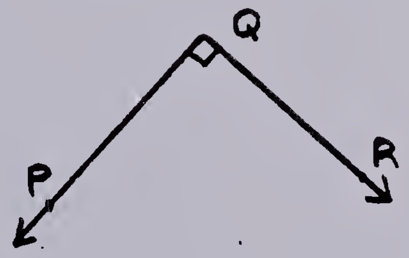
Base _______
Height _______
Area _______

ANGLE MEASURE









ANGULAR MEASURE UNIT

After completing this unit you should be able to:

1. Name any angle and its component parts.

2. Estimate the size of a given angle.

3. Measure a given angle in degrees, using a protractor.

4. Draw an angle of given size, using the protractor.

If at any time, you are unsure of the concepts developed in this unit, consult with your fellow students, available mathematics materials or your teacher.

For extra practice, it is advisable to complete the exercises in your consortium student exercise book.

Measurement of Angles

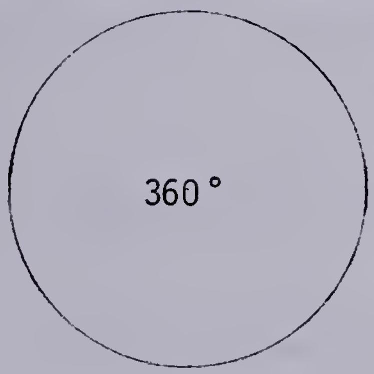
Materials needed: (1) Protractor

(2) Cut outs of left and right side protractors

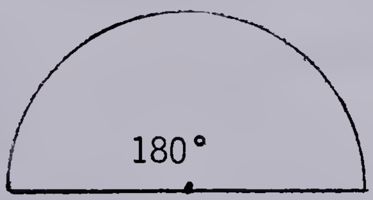
To measure 'amounts of turn' or 'angles' we use the unit called a degree. A complete turn will give a circle and a degree is defined in terms of a circle.

A degree is $\frac{1}{360}$ of a circle.

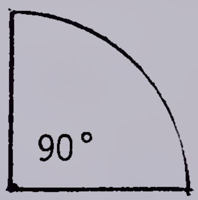
Any angle or amount of turn is measured in terms of this. A circle is a 360 degree (written 360°) turn. A semi-circle or half a turn is 180° and a quarter-turn is 90°.



Circle
(Complete turn)



Semi-Circle
(half-turn)



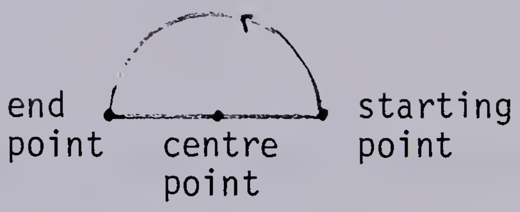
Quarter
Turn

The amount of turn in 1° could be found by (a) dividing the circle into 360 parts or (b) dividing the semi-circle into 180 parts or (c) dividing the quarter turn into 90 parts. This task would show that 1° is a very small amount of turn.

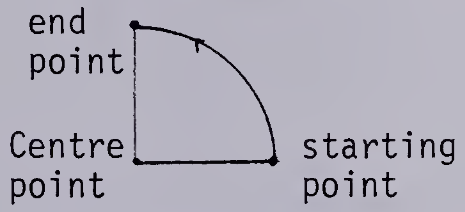
To draw a turn we must have a centre point and a starting point and an end point. For the circle we have a centre and our start and end points are

the same since we make a complete turn.

For the semi-circle we have a centre point and a starting point and an end point half way around

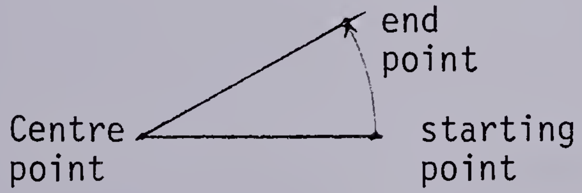


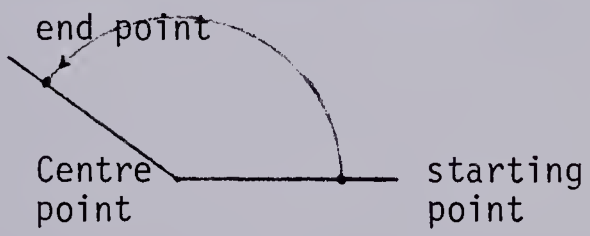
For the quarter turn we have a centre point, a starting point and an end point.



The turn is made about the centre and the start and end points show how much turn was made.

Since an angle is an amount of turn swept out by a moving point, it must have a centre point about which the turn is made, a starting point and and end point. For example,

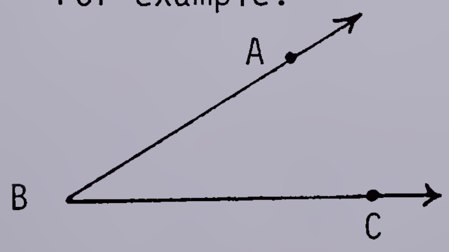




We call the centre point about which the turn is made the VERTEX of the angle. The parts from the vertex to the starting point and vertex to the end point are called <u>RAYS</u>.

We can now describe an ANGLE as the amount of turn described by two rays which meet at a vertex.

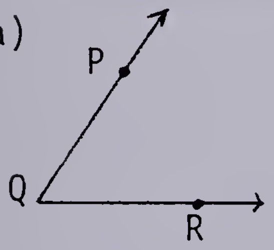
For example:

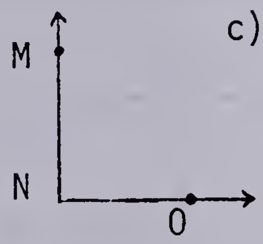


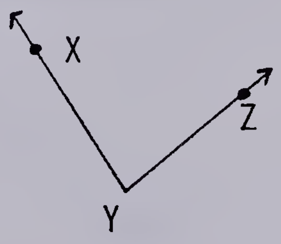
Angle ABC (Written $\angle ABC$) consists of two rays $\overrightarrow{BA}$ and $\overrightarrow{BC}$ which meet at the vertex B. The amount of turn is shown by the distance between $\overrightarrow{BC}$ and $\overrightarrow{BA}$.

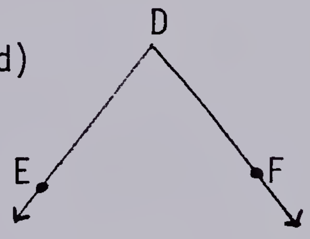
An angle can be named by the letters describing the rays and vertex <u>or</u> just by the letter describing its vertex. The above angle can be named either $\angle$ ABC or $\angle$ B.

Exercises: For the given angles name the rays, vertex and give two names for each angle.

a) 

b) 

c) 

d) 

Rays (i) ____	Rays (i) ____	Rays (i) ____	Rays (i) ____
(ii) ____	(ii) ____	(ii) ____	(ii) ____
Vertex ______	Vertex ______	Vertex ______	Vertex ______
Angle (i) ___	Angle (i) ___	Angle (i) ____	Angle (i) ___
(ii) ___	(ii) ___	(ii) ____	(ii) ___

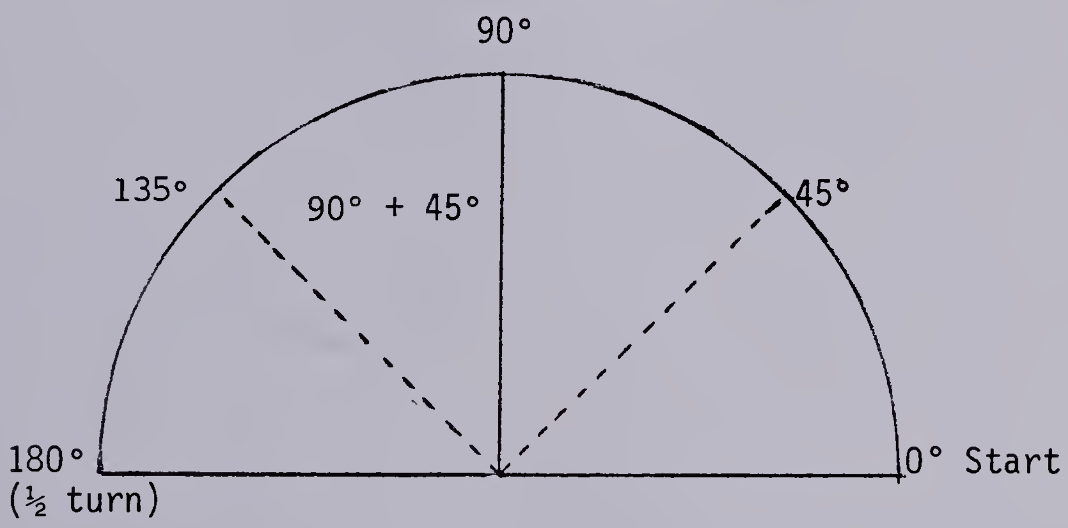
Estimating Angle Measures

Recall that angles are part of a turn thus to determine the size of an angle we determine the amount of a turn it is.

A circle is a complete turn and measures 360°.

A semi-circle is a half turn and measures 180°.

A quarter circle is a quarter turn and measures 90°.



To estimate the size of an angle we check to see if it is between 0° & 90° (less than a quarter turn) or between 90 & 180° (greater than a quarter turn). This gives a reference point for the estimation. To make a better guess we can divide this again probably halfway on each side of the 90° mark. Since 45° is halfway between 0° & 90° & 135° is halfway between 90° & 180° we have established two more points of reference. This helps to more precisely estimate the size of angles.

We can now ask the following questions:

Is an angle between 0° and 45°?

Is an angle between 45° and 90°?

Is an angle between 90° and 135°?

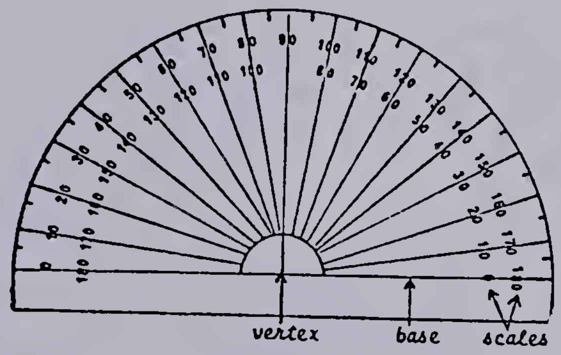
Is an angle between 135° and 180°?

By further sub-dividing the half-turn the estimating of angle size can be very precise.

Exercises: Using a procedure similar to the one above, ESTIMATE the size of the angles on pages 29 & 30 of the students workbook.

Measuring Angle Size

To measure the amount of turn described by an angle we use a PROTRACTOR. A protractor is a semi-circular measuring device with markings of 0 to 180. The markings presents 1° since there are 180° in a half circle.



The protractor has three (3) main parts:

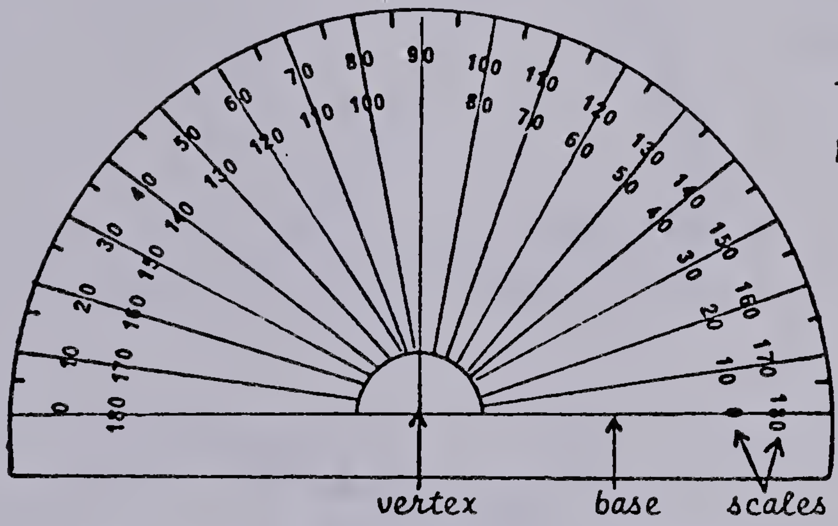
(a) The Vertex is the centre of the protractor and is always placed at the vertex of an angle when measuring.

(b) The base is the line through the vertex to describe the half circle. The base is always placed on one ray of any angle being measured.

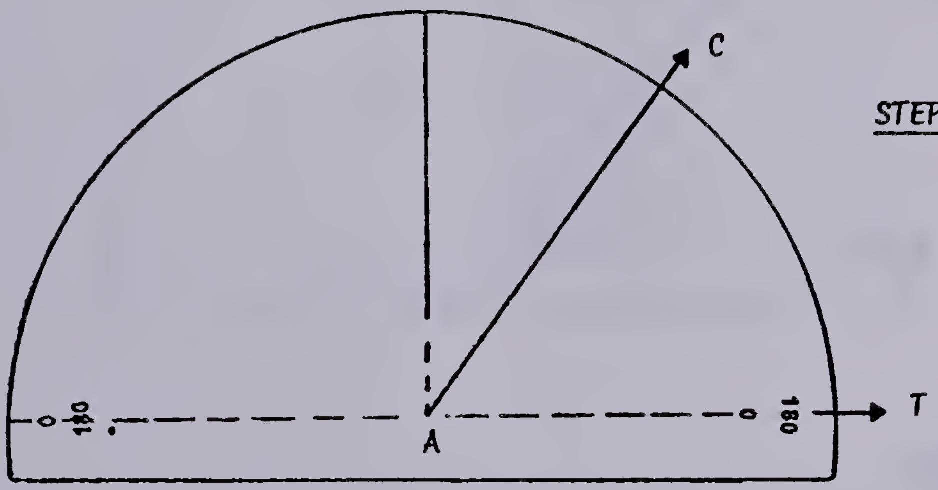
(c) The scales which run from 0 - 180° both clockwise and counter-clockwise. The double marking makes it easy to measure both clockwise and counter-clockwise angles without having to flip the protractor. The base line must always be placed on one ray so that the start point for measuring is "0" and the end ray reading will be the measure of the angle. The "0" point must always lie on one of the rays.

The following six steps indicate how to use the protractor to measure an angle.

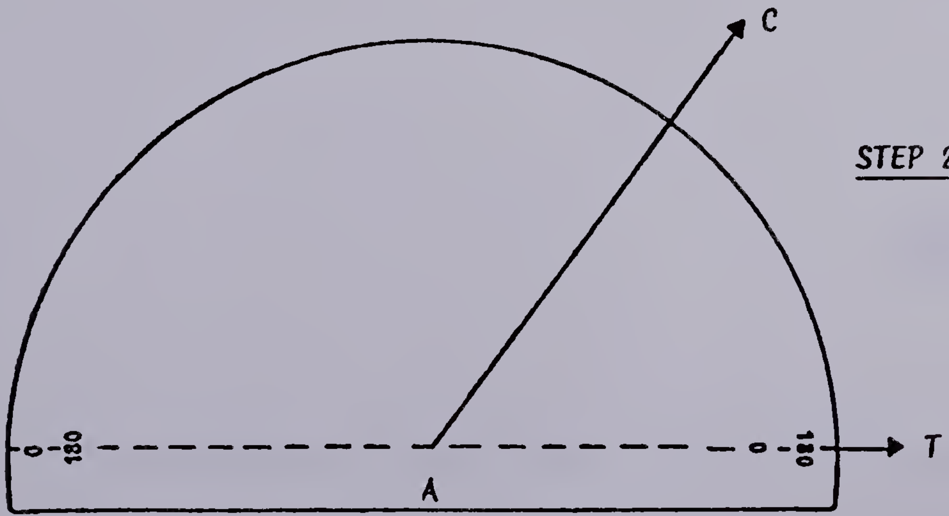
Steps in using a protractor



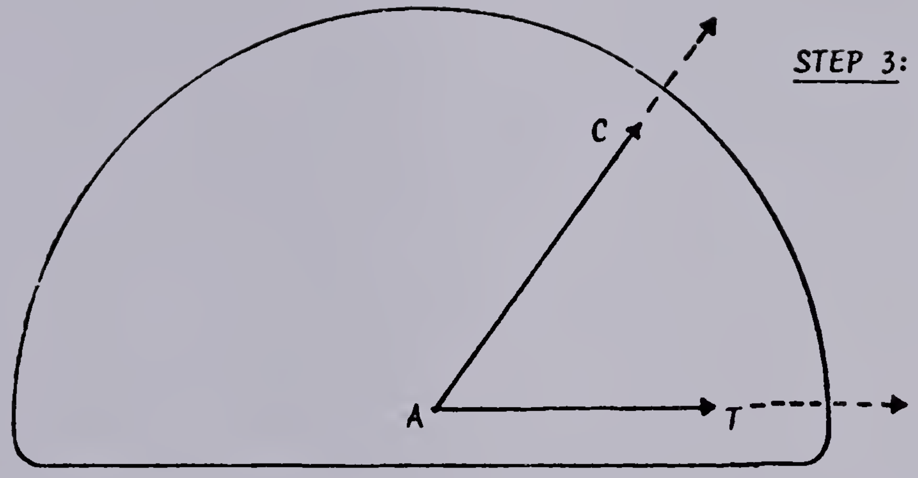
This is your protractor.



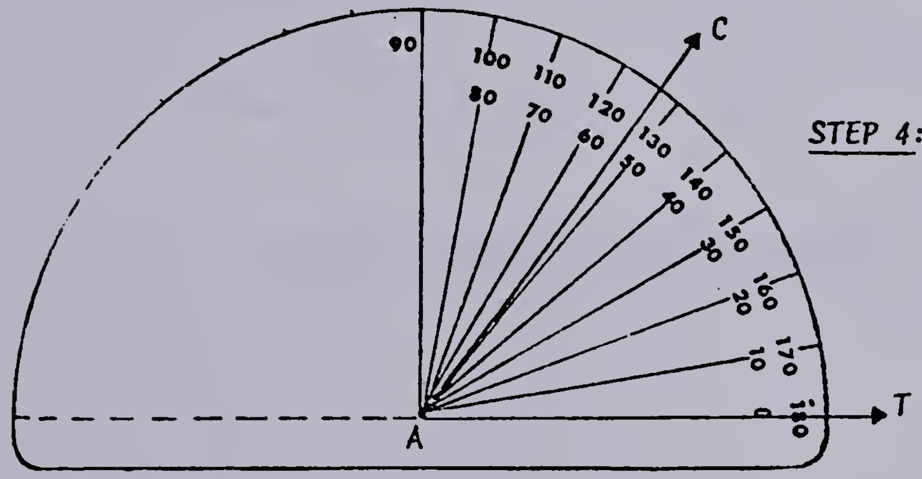
<u>STEP 1</u>: *Place the vertex of your protractor on the vertex of your angle.*



<u>STEP 2</u>: *Place the base of your protractor along one ray of your angle* (MAKING SURE THE ZERO IS ON THE RAY).



STEP 3: If your rays are too short extend them beyond the edge of the protractor.



STEP 4: Locate the other ray of your angle on the appropriate scale of your protractor.

STEP 5: Read off the measure correctly. eg. 53^0

STEP 6: State your answer in the correct form. $\angle CAT = 53^0$

Do the exercises on pages 24-30 of the student exercise workbook.

APPENDIX F

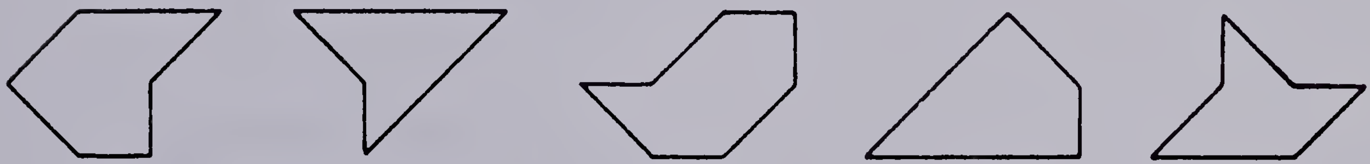
INTERVIEW PROTOCOL QUESTIONNAIRE

The purpose of this interview is to determine some of your thoughts about Mathematics, Math Instruction and how you solve problems. This is not an evaluation of you, but is for my information only. Speak openly and fully in answer to the questions.

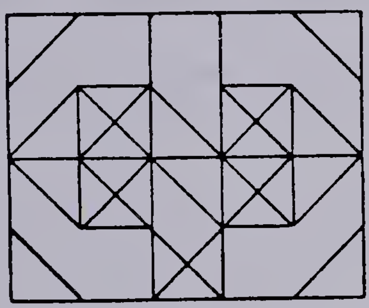
1. Do you do well in Math?
2. Do you like Math?
3. What's your favorite part of Math?
4. How are you taught Math?
5. Is their another way that you would prefer?
6. Has your classroom instruction changed in any way recently? If so, how?

At this point I will give you some problems to complete. Please describe fully how you would attempt to solve them. Tell me what you are thinking as you do the problems.

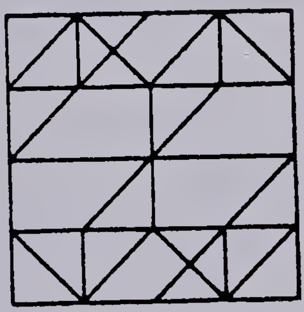
I. One of the following simple figures is contained in the complex figure, would you please indicate which it is and how you will approach the problem. (Please describe in detail your method of approach in doing the problem).



A B C D E



A B C D E

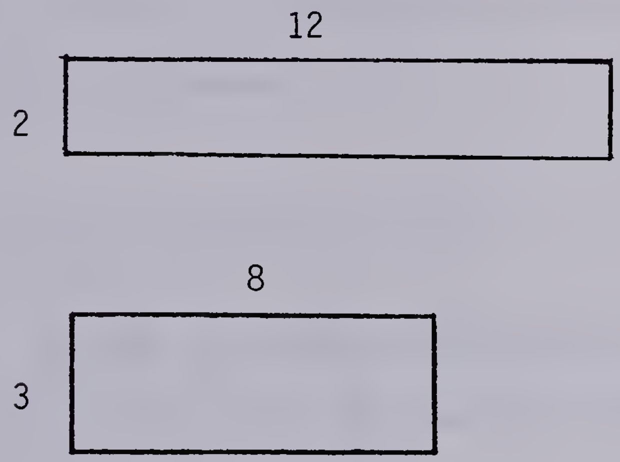


A B C D E

II. A piece of board is to be cut in two equal pieces to completely cover a hole.

The hole is 2 x 12

The board is 3 x 8



Can you do it? If yes, how?

If not, what is the least number of cuts you would make to get the board to cover the hole?

INTERVIEW OBSERVATIONS

1. Do you do well in Mathematics?

Of the 16 students interviewed, 14 indicated they did well, one indicated that it depended on the teacher, and another indicated about average achievement.

2. Do you like Mathematics?

Of the 16 students interviewed, 12 indicated they liked mathematics, 3 indicated dislike and another indicated liking some parts of mathematics.

3. What is your favorite part of mathematics?

Measurement	--	3	(1 FI, 2 FD)
Geometry	--	2	(2 FI)
Fractions	--	3	(1 FI, 2 FD)
All Same	--	6	(3 FI, 3 FD)
None	--	2	(1 FI, 1 FD)

4. How are you taught Mathematics?

Students answers indicated correct perceptions of their instructional strategy. However, the students in the student-centered strategy indicated that usually a math class consists of the teacher explaining, doing samples, giving questions and correcting them. It was only with further questioning that they indicated the correct perception of their student-centered strategy.

5. Is there another way that you would like to be taught?

Of the 16 students interviewed, 14 preferred mathematics instruction to be teacher-centered in nature. Two field-independent students in student-centered strategies indicated preference for this type of strategy.

6. Has your classroom instruction changed in any way recently? If so, how?

The 8 students in the teacher-centered strategy indicated no change in teaching strategy.

All 8 students in the student-centered strategy indicated some change in teaching strategy from before. They indicated that they were required to do more work and given less teacher explanation.

One student indicated that there was "more in the books. We had to figure it out".

Another student indicated there was some change but not a real difference. On further questioning he indicated that "we did the measuring, but would probably have to measure things anyway".

Problem 1. Sample HFT problem.

Twelve of the students including all the field-independent students indicated the following of a procedure in attempting the items. They tried choice A, then B, etc. Also, they indicated looking for details including corners and where lines cross. Two field-independent students indicated that sometimes we might see them "right off".

Two of the students indicated no procedure and haphazardly attempted the items.

Two students indicated that they tried sample A in all the complex items, then tried Sample B, etc.

Problem 2. Cutting board to fit the hole.

No student successfully showed the single cut for the board to fit the hole.

Three students (1 FI, 2 FD) gave no solution and indicated it couldn't be done.

Five students (3 FI, 2 FD) gave a solution indicating only two cuts; a 2 x 8 cut and halfing the remaining part.

Four students (1 FI, 3 FD) gave a solution indicating three cuts; a 2 x 8 cut and cutting the remaining into pieces.

Four students (3 FI, 1 FD) indicated that the board would have to be cut into small pieces. No specific number was given.

After giving an answer, 15 students quickly indicated no possible way of making only one cut, one student indicated she would have to think about it.

A P P E N D I X   G

VARIABLES AND PREDICTION EQUATIONS
TABLES XXX and XXXI

TABLE XXX

DEFINITION OF VARIABLES FOR THE STUDY

Variable	Measures for Variables
X_1	IQ
X_2	Skemp's SK 6(I)
X_3	Skemp's SK 6(II)
X_4	HFT (Cf-1)
X_5	Mathematics Achievement
X_6	Concept Attainment
X_7	Problem Solving
X_8	1 for Male, 0 Otherwise
X_9	1 for Female, 0 Otherwise
X_{10}	1 for Student-Centered, 0 Otherwise
X_{11}	1 for Teacher-Centered, 0 Otherwise
X_{12}	$X_4 . X_{10} = X_4$ if Student-Centered, 0 Otherwise
X_{13}	$X_4 . X_{11} = X_4$ if Teacher-Centered, 0 Otherwise
X_{14}	$X_5 . X_8 = X_5$ if Male, 0 Otherwise
X_{15}	$X_5 . X_9 = X_5$ if Female, 0 Otherwise
X_{16}	$X_6 . X_8 = X_6$ if Male, 0 Otherwise
X_{17}	$X_6 . X_9 = X_6$ if Female, 0 Otherwise
X_{18}	$X_7 . X_8 = X_7$ if Male, 0 Otherwise
X_{19}	$X_7 . X_9 = X_7$ if Female, 0 Otherwise
X_{20}	$X_4 . X_8 = X_4$ if Male, 0 Otherwise
X_{21}	$X_4 . X_9 = X_4$ if Female, 0 Otherwise

TABLE XXXI

PREDICTION EQUATIONS AND WEIGHTS

Model 01

$$Y_5 = A_0U + A_1X_1 + A_2Y_2 + A_3X_3 + E$$

RSQ = 0.38766319

Variable	Regression Weight
1	0.14038866
2	0.14981487
3	0.06295782
Constant	-5.60567188

Model 02

$$Y_6 = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + E$$

RSQ = 0.33571619

Variable	Regression Weight
1	0.09257668
2	0.08875588
3	0.01092898
Constant	-1.64842892

Model 03

$$Y_7 = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + E$$

RSQ = 0.2345604

NB. Y_5 = Math Achievement; Y_6 = Concept Attainment; Y_7 = Problem Solving

Model 03 Cont'd.

Variable	Regression Weight
1	0.04781087
2	0.06116567
3	0.05188325
Constant	-3.95711040

Model 04

$$Y_5 = A_0U + A_4X_4 + E$$

RSQ = 0.09847021

Variable	Regression Weight
4	0.26218957
Constant	10.40176868

Model 05

$$Y_6 = A_0U + A_4X_4 + E$$

RSQ = 0.07949007

Variable	Regression Weight
4	0.14812248
Constant	8.49846649

Model 06

$$Y_7 = A_0U + A_4X_4 + E$$

RSQ = 0.06303889

Model 06 Cont'd.

Variable	Regression Weight
4	0.11406723
Constant	1.90330029

Model 07

$$Y_5 = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + E$$

RSQ = 0.39174426

Variable	Regression Weight
1	0.13405553
2	0.14160318
3	0.06011770
4	0.05966510
Constant	-5.31234932

Model 08

$$Y_6 = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + E$$

RSQ = 0.33832020

Variable	Regression Weight
1	0.08955212
2	0.08477349
3	0.00915657
4	0.02973342
Constant	-1.51290894

Model 09

$$Y_7 = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + E$$

RSQ = 0.23795921

Variable	Regression Weight
1	0.04495958
2	0.05788528
3	0.04924894
4	0.02985839
Constant	-3.84212780

Model 10

$$Y_5 = A_0U + A_1X_1 + A_4X_4 + E$$

RSQ = 0.34922236

Variable	Regression Weight
1	0.17588441
4	0.09277203

Model 11

$$Y_6 = A_0U + A_1X_1 + A_4X_4 + E$$

RSQ = 0.31303722

Variable	Regression Weight
1	0.10673196
4	0.04531478
Constant	-1.64061165

Model 12

$$Y_7 = A_0U + A_1X_1 + A_4X_4 + E$$

RSQ = 0.19414341

Variable	Regression Weight
1	0.06915246
4	0.04745733
Constant	-4.66588688

Model 13

$$Y_5 = A_0U + A_2X_2 + A_3X_3 + A_4X_4 + E$$

RSQ = 0.28470725

Variable	Regression Weight
2	0.21405071
3	0.14251605
4	0.12661188
Constant	5.37850761

Model 14

$$Y_6 = A_0U + A_2X_2 + A_3X_3 + A_4X_4 + E$$

RSQ = 0.21834588

Variable	Regression Weight
2	0.13083314
3	0.6622617
4	0.07467170
Constant	5.64338589

Model 15

$Y_7 = A_0U + A_2X_2 + A_3X_3 + A_4X_4 + E$

RSQ = 0.19749999

Variable	Regression Weight
2	0.08120291
3	0.07761727
4	0.05247566
Constant	-0.24953896

Model 16

$Y_5 = A_0U + A_{12}X_{12} + A_{13}X_{13} + E$

RSQ = 0.09753376

Variable	Regression Weight
12	0.26362852
13	0.25726340
Constant	10.41336918

Model 17

$Y_6 = A_0U + A_{12}X_{12} + A_{13}X_{13} + E$

RSQ = 0.07745260

Variable	Regression Weight
12	0.14380314
13	0.14771507
Constant	8.51728058

Model 18

$$Y_7 \quad = \quad A_0U + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.0631907

Variable	Regression Weight
12	0.11982545
13	0.10954844
Constant	1.98608765

Model 19

$$Y_5 \quad = \quad A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.39337170

Variable	Regression Weight
1	0.13373846
2	0.14657138
3	0.06123497
12	0.04147580
13	0.07013098
Constant	-5.36193562

Model 20

$$Y_6 \quad = \quad A_0U + A_1X_1 + A_2X_2 + A_3Y_3 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.34016865

Model 20 Cont'd.

Variable	Regression Weight
1	0.08886757
2	0.08789104
3	0.01190501
12	0.01411419
13	0.03692385
Constant	-1.50662613

Model 21

$$Y_7 = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.2387276

Variable	Regression Weight
1	0.04471324
2	0.05917059
3	0.05024376
12	0.02437353
13	0.03280939
Constant	-3.84604263

Model 22

$$Y_5 = A_0U + A_1X_1 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.34939134

Model 22 Cont'd.

Variable	Regression Weight
1	0.17602856
12	0.09052922
13	0.09513905
Constant	-6.32479668

Model 23

$$Y_6 = A_0U + A_1X_1 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.31327736

Variable	Regression Weight
1	0.10724186
12	0.03749675
13	0.04868930
Constant	-1.67489147

Model 24

$$Y_7 = A_0U + A_1X_1 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.19492239

Variable	Regression Weight
1	0.06861074
12	0.05294828
13	0.04794662
Constant	-4.63853836

Model 25

$$Y_5 = A_0U + A_2X_2 + A_3X_3 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.28791213

Variable	Regression Weight
2	0.21913783
3	0.14590308
12	0.09900929
13	0.14242012
Constant	5.27646446

Model 26

$$Y_6 = A_0U + A_2X_2 + A_3X_3 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.22172165

Variable	Regression Weight
2	0.13695723
3	0.06676285
12	0.05468894
13	0.08461017
Constant	5.55700111

Model 27

$$Y_7 = A_0U + A_2X_2 + A_3X_3 + A_{12}X_{12} + A_{13}X_{13} + E$$

RSQ = 0.19910061

Model 27 Cont'd.

Variable	Regression Weight
2	0.08212371
3	0.07890989
12	0.04581591
13	0.05708612
Constant	-0.27945226

Model 28

$$Y_5 = A_0U + A_1X_1 + E$$

RSQ = 0.33863044

Variable	Regression Weight
1	0.18945172
Constant	-6.83297443

Model 29

$$Y_6 = A_0U + A_1X_1 + E$$

RSQ = 0.30664635

Variable	Regression Weight
1	0.11335895
Constant	-1.89777184

Model 30

$$Y_7 = A_0U + A_1X_1 + E$$

RSQ = 0.18476874

Variable	Regression Weight
1	0.07609282
Constant	-4.93520832

Model 31

$$Y_5 = A_0U + A_2X_2 + A_3X_3 + E$$

RSQ = 0.26458842

Variable	Regression Weight
2	0.23881122
3	0.15900172
Constant	5.85846615

Model 32

$$Y_6 = A_0U + A_2X_2 + A_3X_3 + E$$

RSQ = 0.20062894

Variable	Regression Weight
2	0.14724674
3	0.07453454
Constant	5.91129589

Model 33

$$Y_7 = A_0U + A_2X_2 + A_3X_3 + E$$

$RSQ = 0.18606579$

Variable	Regression Weight
2	0.09154646
3	0.08446725
Constant	-0.05283445

APPENDIX H

RAW DATA

RAW DATA

VARIABLE	TEST
1	Lorge-Thorndike Composite IQ
2	Skemp's SK 6(I)
3	Skemp's SK 6(II)
4	Hidden Figures Test
5	Mathematics Achievement
6	Concept Attainment Score
7	Problem Solving Score
8	Sex (1 - Male, 0 - Female)
9	(1 - Student-Centered; 0 - Teacher-Centered)

ID	1	2	3	4	5	6	7	8	9
1.	90	18	14	3	11	9	2	1	1
2.	105	20	17	5	10	8	2	1	1
3.	77	11	10	13	3	3	0	1	1
4.	101	6	10	7	9	8	1	0	1
5.	108	24	21	10	7	6	1	1	1
6.	116	16	26	12	17	13	4	0	1
7.	101	13	9	5	9	6	3	0	1
8.	131	28	41	14	19	13	6	1	1
9.	118	30	25	16	19	13	6	0	1
10.	93	18	18	4	7	6	1	0	1
11.	105	12	12	2	15	13	2	0	1
12.	105	29	20	10	9	8	1	1	1
13.	102	17	1	8	9	9	0	1	1
14.	119	23	18	15	14	11	3	1	1
15.	110	29	26	15	18	12	6	0	1
16.	87	27	18	7	9	7	2	1	1
17.	64	11	5	14	6	5	1	1	1
18.	101	29	19	20	20	11	9	0	1
19.	111	24	20	9	15	12	3	1	1
20.	123	24	29	13	17	13	4	1	1
21.	90	13	11	11	6	6	0	0	1
22.	108	18	24	12	14	11	3	1	1
23.	99	29	19	13	9	9	0	0	1

ID	1	2	3	4	5	6	7	8	9
24.	105	20	18	10	9	8	1	0	1
25.	103	21	23	10	12	11	1	0	1
26.	84	12	6	9	13	11	2	1	1
27.	112	25	10	10	9	8	1	0	1
28.	85	22	21	9	11	7	4	0	1
29.	112	17	15	10	13	13	0	1	1
30.	117	27	26	17	16	13	3	0	1
31.	119	26	15	7	10	9	1	1	1
32.	82	15	12	10	10	10	0	1	1
33.	107	17	13	8	11	9	2	0	1
34.	104	28	17	4	21	12	9	1	1
35.	101	19	11	17	19	13	6	1	1
36.	115	26	30	12	17	11	6	0	1
37.	108	18	21	7	15	12	3	1	1
38.	138	18	19	17	14	9	5	1	1
39.	87	18	16	7	3	3	0	0	1
40.	119	22	18	19	22	12	10	1	1
41.	85	22	14	8	9	6	3	0	1
42.	117	25	28	11	17	10	7	1	1
43.	101	19	7	7	11	10	1	0	1
44.	94	16	10	0	8	6	2	0	1
45.	86	4	9	11	8	4	4	1	1
46.	88	12	2	8	6	6	0	1	1

ID	1	2	3	4	5	6	7	8	9
47.	87	17	8	6	5	4	1	0	1
48.	109	21	11	11	16	12	4	1	1
49.	92	14	16	3	8	7	1	0	1
50.	113	22	16	11	19	12	7	0	1
51.	103	12	6	11	13	9	4	1	1
52.	107	24	15	16	15	10	5	0	1
53.	103	20	31	1	21	12	9	1	1
54.	97	23	13	7	17	13	4	1	1
55.	81	18	3	4	4	4	0	0	1
56.	103	28	19	13	11	10	1	0	1
57.	115	28	16	25	11	10	1	1	1
58.	115	28	16	6	20	13	7	0	1
59.	83	26	9	1	10	6	4	1	1
60.	83	11	0	3	11	10	1	1	1
61.	98	19	15	13	12	9	3	0	1
62.	102	16	8	5	10	9	1	0	1
63.	121	22	16	9	12	10	2	1	1
64.	109	23	15	9	13	11	2	0	1
65.	107	19	5	7	19	15	4	1	1
66.	117	11	7	5	17	9	8	1	1
67.	129	20	21	6	15	14	1	1	1
68.	100	21	14	22	14	11	3	0	1
69.	95	26	10	2	14	11	3	1	1

ID	1	2	3	4	5	6	7	8	9
70.	92	18	1	2	8	7	1	1	1
71.	96	16	9	10	16	12	4	0	1
72.	111	24	19	13	18	13	5	1	1
73.	90	7	2	8	8	8	0	1	1
74.	115	23	24	18	14	14	0	1	1
75.	116	24	13	10	18	12	6	0	1
76.	121	26	24	13	17	12	5	0	1
77.	99	23	17	0	17	12	5	1	1
78.	123	28	30	11	15	10	5	0	1
79.	128	27	23	16	17	13	4	1	1
80.	133	22	13	8	18	14	4	0	1
81.	116	22	14	2	17	12	5	0	1
82.	126	26	19	9	20	13	7	1	1
83.	90	18	0	9	13	9	4	1	1
84.	106	27	24	10	18	13	5	0	1
85.	121	19	25	8	14	10	4	1	1
86.	121	23	11	17	14	12	2	0	1
87.	107	24	11	10	16	13	3	1	0
88.	88	16	8	6	14	10	4	1	0
89.	106	18	16	14	13	8	5	1	0
90.	110	21	18	4	14	12	2	1	0
91.	113	28	22	22	18	10	8	1	0
92.	114	22	31	12	15	12	3	1	0

ID	1	2	3	4	5	6	7	8	9
93.	113	18	25	11	9	8	1	1	0
94.	105	23	9	5	13	11	2	1	0
95.	100	28	25	9	19	12	7	1	0
96.	104	10	16	3	10	9	1	0	0
97.	132	27	21	11	22	12	10	0	0
98.	98	13	24	4	13	8	5	0	0
99.	96	17	7	16	5	5	0	0	0
100.	98	18	9	10	9	9	0	1	0
101.	123	18	23	10	14	10	4	1	0
102.	96	16	8	10	10	7	3	0	0
103.	111	21	13	13	6	4	2	0	0
104.	118	25	26	9	16	13	3	0	0
105.	76	12	7	6	9	6	3	0	0
106.	115	16	7	11	7	7	0	0	0
107.	110	17	0	6	14	10	4	1	0
108.	125	25	28	11	19	12	7	1	0
109.	91	14	7	6	5	5	0	1	0
110.	89	16	3	12	11	10	1	0	0
111.	111	12	12	6	7	7	0	1	0
112.	78	3	4	9	7	7	0	0	0
113.	94	23	9	9	14	12	2	1	0
114.	101	13	13	5	13	10	3	0	0
115.	90	16	16	4	8	7	1	1	0

ID	1	2	3	4	5	6	7	8	9
116.	97	16	14	5	7	7	0	0	0
117.	115	15	9	23	17	12	5	1	0
118.	96	15	6	2	15	11	4	0	0
119.	103	19	18	12	14	13	1	1	0
120.	111	23	16	11	15	14	1	0	0
121.	131	30	24	22	20	13	7	1	0
122.	94	17	14	5	14	12	2	0	0
123.	92	22	18	7	11	10	1	1	0
124.	105	18	4	7	13	10	3	0	0
125.	115	19	11	5	16	11	5	1	0
126.	121	22	14	1	15	13	2	1	0
127.	95	11	10	14	12	8	4	1	0
128.	90	18	11	11	13	11	2	0	0
129.	106	20	8	11	15	13	2	1	0
130.	98	18	17	13	15	11	4	0	0
131.	88	15	17	9	14	12	2	1	0
132.	113	7	12	3	9	8	1	0	0
133.	98	24	16	6	8	8	0	1	0
134.	95	25	18	10	11	9	2	0	0
135.	105	23	21	7	21	15	6	1	0
136.	95	16	19	12	13	9	4	0	0
137.	107	12	16	3	19	13	6	0	0
138.	106	18	20	15	14	12	2	1	0

ID	1	2	3	4	5	6	7	8	9
139.	119	25	28	25	23	15	8	0	0
140.	126	19	25	19	15	11	4	0	0
141.	103	22	21	4	11	7	4	1	0
142.	98	21	10	5	11	9	2	1	0
143.	116	27	20	14	16	11	5	1	0
144.	96	23	21	10	8	8	0	1	0
145.	103	24	19	5	8	7	1	1	0
146.	108	19	16	16	10	9	1	1	0
147.	122	24	4	20	10	9	1	1	0
148.	86	8	11	10	7	7	0	0	0
149.	104	20	20	11	19	15	4	0	0
150.	106	23	19	2	8	6	2	1	0
151.	82	19	7	9	12	12	0	1	0
152.	92	17	10	5	12	9	3	1	0
153.	98	22	17	7	12	10	2	0	0
154.	106	17	7	9	12	11	1	0	0
155.	102	16	14	6	13	9	4	0	0
156.	106	28	18	15	13	10	3	0	0
157.	117	23	25	20	21	15	6	1	0
158.	84	16	2	2	5	3	2	0	0
159.	99	21	9	10	16	12	4	1	0
160.	104	21	4	10	13	11	2	1	0
161.	101	14	2	4	10	8	2	0	0

ID	1	2	3	4	5	6	7	8	9
162.	85	21	5	7	9	9	0	0	0
163.	90	18	4	7	16	10	6	1	0
164.	111	17	14	11	14	10	4	0	0
165.	96	24	4	11	12	9	3	1	0
166.	104	22	13	5	13	12	1	1	0
167.	112	28	18	6	10	9	1	1	0
168.	119	16	19	9	13	11	2	0	0
169.	121	22	7	23	20	14	6	1	0
170.	97	19	15	10	10	7	3	0	0
171.	129	24	18	12	16	12	4	0	0
172.	91	13	7	8	10	8	2	1	0
173.	99	14	6	9	12	8	4	1	0
174.	105	21	3	5	13	10	3	1	0
175.	118	21	29	16	14	9	5	0	0
176.	93	22	1	6	10	8	2	1	0
177.	102	19	13	10	12	12	0	0	0

TABLE XXXII

VARIABLE MEANS, STANDARD DEVIATIONS, AND PROBABILITY LEVELS RELATED TO INSTRUCTIONAL DIFFERENCES

		STUDENT-CENTERED		TEACHER-CENTERED		Probability
		MEAN	STD. DEV.	MEAN	STD. DEV.	Level
1.	IQ	104.72	14.33	103.73	11.95	0.61
2.	SK 6(I)	20.47	5.87	19.15	5.00	0.11
3.	SK 6(II)	15.49	7.95	13.80	7.66	0.14
4.	HFT	9.60	5.08	9.52	5.18	0.92
5.	Math Achievement	13.08	4.59	12.74	3.98	0.60
6.	Concept Attainment	9.91	2.86	9.92	2.54	0.97
7.	Problem Solving	3.17	2.48	2.82	2.16	0.31